MINING engineering

FEBRUARY 1954

ANNUAL REVIEW NUMBER

WILFLEY PUMPS

NEW Potash Refining Plants

Feature Both Sand and Acid Pumps by Wilfley

Wilfley pumps were chosen for new potash refining plants in Carlsbad, New Mexico...for efficient, low cost production...for continuous, economical performance without attention.

Wherever installed, these famous pumps—*both* Sand and Acid—consistently increase production and create substantial dollar savings in power and maintenance.

Individual engineering on every application. Write, wire, or phone for complete details.

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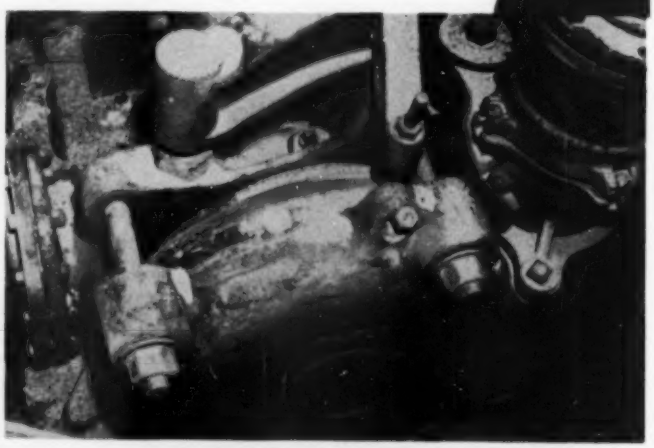
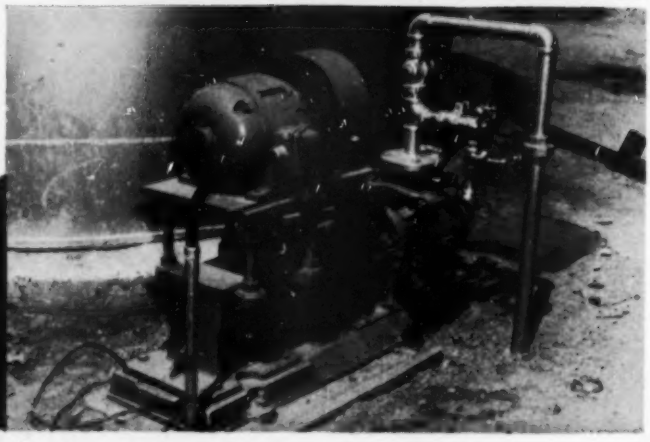
- **Stepped-up production**
- **Continuous operation without attention**
- **Minimum replacement of parts**
- **Designed for simple installation**
- **Economical pump size for every requirement**



Wilfley Sand Pump

"COMPANIONS IN ECONOMICAL OPERATION"

Wilfley Acid Pump



MINING engineering

VOL. 6 NO. 2 FEBRUARY 1954

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ANNUAL REVIEW NUMBER

COVER

The miner with his cap lamp, always drifting out a little farther, always putting in that "one more round," symbolizes to cover artist Herb McClure the spirit behind the developments chronicled in the Annual Review.

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—Personnel Service—

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Mining Engineer, BSEM, 23, single. Six months experience mining engineer trainee, 2 years experience as mechanical engineer contract appraiser. Military service ended January 1954; available short notice. Fair Spanish. Foreign location desired. M-59.

POSITIONS OPEN

Executive Assistant—Mining and Exploration, 30 to 40, with minimum of 5 years experience in metal mining (preferably nonferrous, not coal) practices and knowledge of metal mining and exploration companies. Some exploration experience desirable. College degree preferred. Duties include engineering, accounting, and legal work. Some traveling. Headquarters, New York, N. Y. Y9547.

Assistant Professor in mineral dressing with Master's degree, preferably with some experience. Salary open. Location, Pacific Northwest. Y9226S.

Administrative Engineer for well-established company. Broad experience in mine operating and administrative fields. Salary, $15,000 to $18,000 a year depending on experience and qualifications. Location, West. Y8941.

Placer Development Engineer, 35 to 50, experienced in placer examination and operation of dragline dredges, hydraulics, sluicing, high lift pumping. Experience in reservoir construction and water distribution methods also needed. To function as assistant to chief engineer. Three-year contract. Salary, $8500 a year tax exempt in U. S. currency. Quarters and living allowance. Location, Ethiopia. F9129.

Mining Engineer, young, graduate, with some experience in surveying and mapping. Should be able to assume responsibility and get along well with associates. Duties will include mine and surface surveying and mapping, calculating, and performing other related engineering work. Salary to start, $4200 a year with opportunities for advancement and salary increase. Location, South. Y8371.

Mining Engineer, 25 to 35, to sell coal mining equipment. Must have had at least 5 years experience in modern, underground coal mining, 2 years of which were in a supervisory capacity. Will make market survey and direct sales of this equipment. Sixty-day training period. About 50 pct of time traveling throughout eastern U. S. Headquarters, New Jersey. Y9096.

Maintenance Engineer, engineering degree, up to 45, for a manufacturer of minerals. Must have had at least 3 years experience in maintenance and repair of heavy equipment, and must have knowledge of chemical or mining operations. Will maintain and repair heavy equipment. C1595(c).

Mining Engineer, young, to supervise strip mining and milling operations covering manganese project. Salary, $6000 a year. Location, Virginia. Y9590.

COAL MINE SUPERINTENDENT— age 50 married. 15 years as mining engineer, 13 years as superintendent. Experience with conveyors and all types of mechanical loading equipment. Have proven ability to oversee complete operation, including labor relations, preparation, maintenance of equipment, safety, and underground operations. Desires position as superintendent for progressive mining company.

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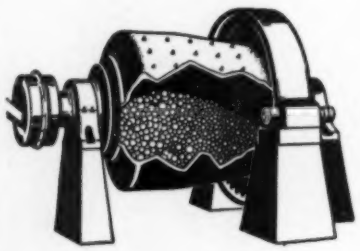
WANTED: Hydrometallurgical Engineer for position in rapidly expanding long range program. Experience in process development, design, operation and administration desirable. Ability to deal with people important. Starting salary $8360 to $9360. Write: U. S. Atomic Energy Commission, Grand Junction, Colorado.

MINE SUPERINTENDENT. Applications are invited for the post of Mine Superintendent at Kilembe Mines. Applicants must be mining graduates with extensive experience in control of underground operations including cut and fill, sub-level and glory hole mining methods. Production rate 1400 tons per day. Knowledge of African labor is highly desirable. Salary dependent on qualifications and experience.

Applications stating full details of experience and salary expected to the General Manager, Kilembe Mines Limited, P. O. Kilembe, Uganda.

GRINDING MILLS



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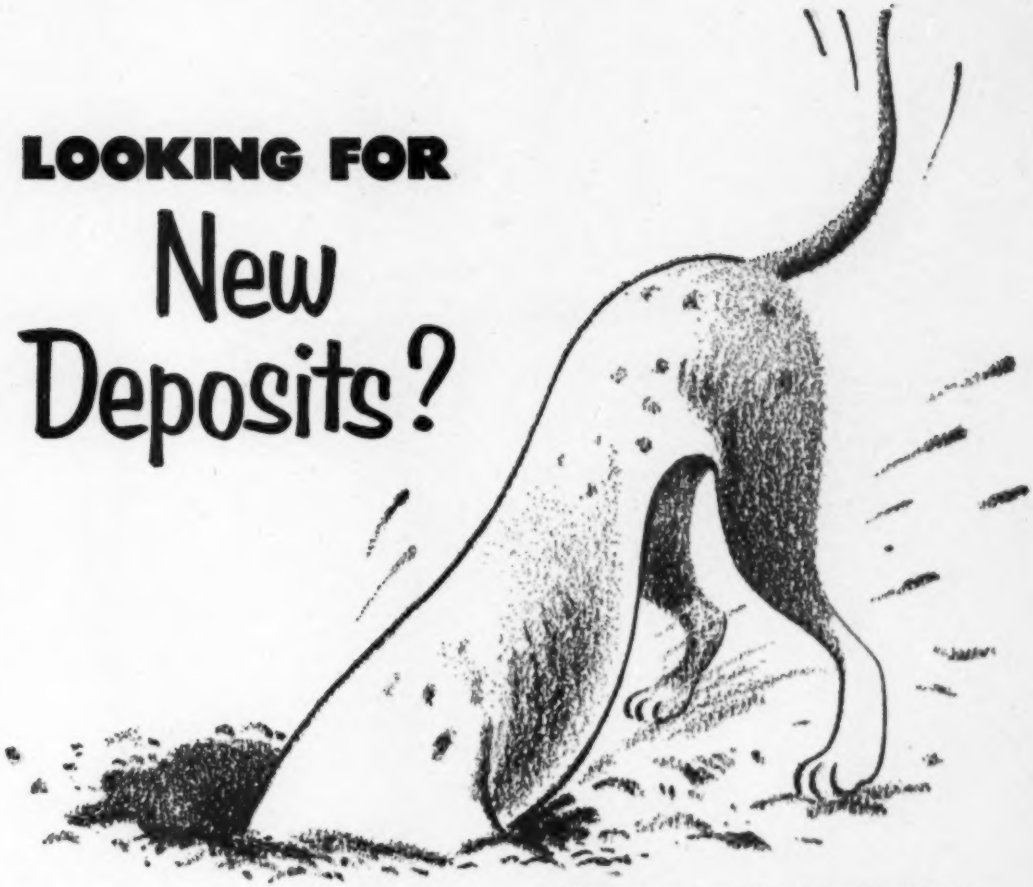
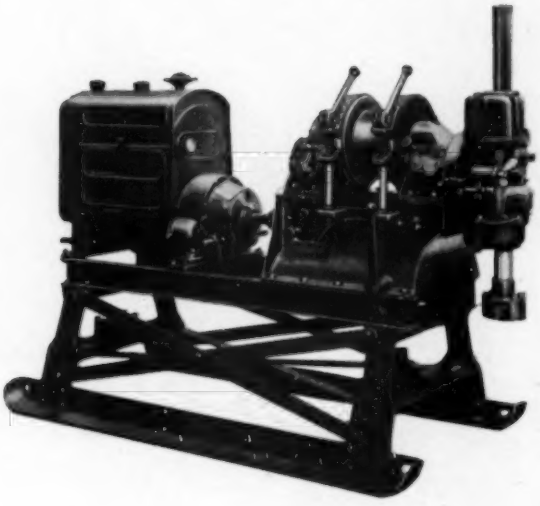
LOOKING FOR New Deposits?





Whether you're mineral prospecting or looking for extensions of existing deposits, you'll wind up with the right information easier and faster by using the skid mounted CP-8 and CP-15 Diamond Core Drills. Specifically engineered to withstand the continued high drilling speeds made possible by bortz bits, they're available with gas, diesel or electric drive for surface drilling and air drive for sampling underground. And they can be readily moved from hole to hole under their own power. Bolted frame permits easy disassembly for transportation to remote sites. With E-EX fittings the CP-8 has capacities to 1250 ft., the CP-15 to 2250 ft. For more complete information, write: *Chicago Pneumatic Tool Company, 8 East 44th Street, New York 17, N. Y.*

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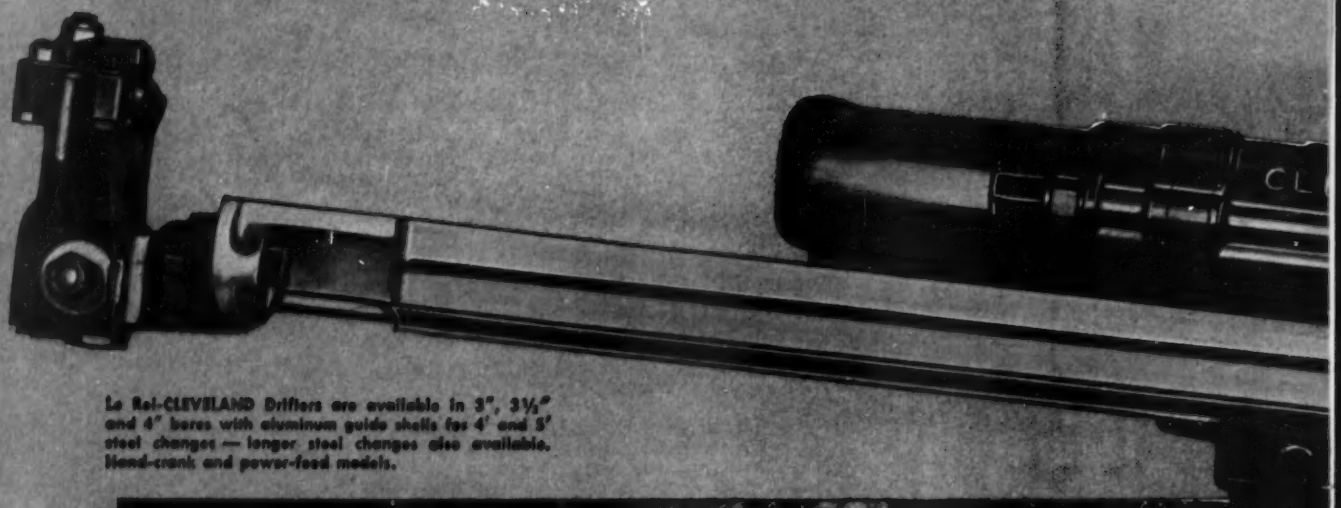

Le Roi-CLEVELAND Drifters are available in 3", 3½" and 4" bores with aluminum guide shells for 4' and 5' steel changes — longer steel changes also available. Hand-crank and power-feed models.

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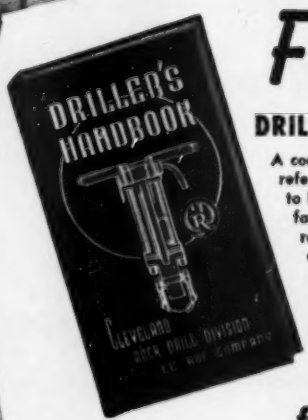
Centralizer can be attached to any Le Roi-CLEVELAND Drifter. Directs the steel effectively, when collaring the hole. Easily cleared out of the way, either by hand or by the nose of the drifter, as the machine is fed forward.



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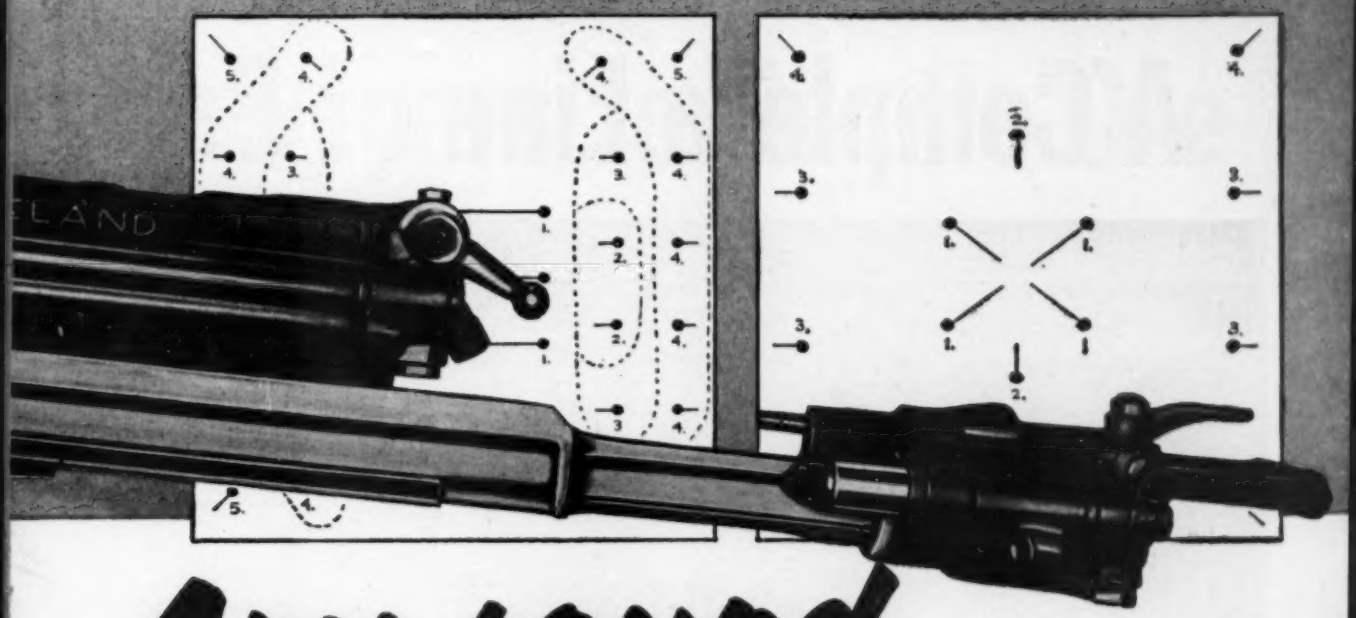

Any round goes faster!

— with Le Roi-CLEVELAND Drifters and aluminum guide shells for 4′ or 5′ steel changes

No matter what pattern they use, your miners drill out the round faster with Le Roi-CLEVELAND Drifters.

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Yes, sir, Le Roi-CLEVELAND Drifters are "just what the doctor ordered," to speed up your drilling cycles, increase your footage, and lower your drilling costs. Ask your Le Roi representative for the whole story.

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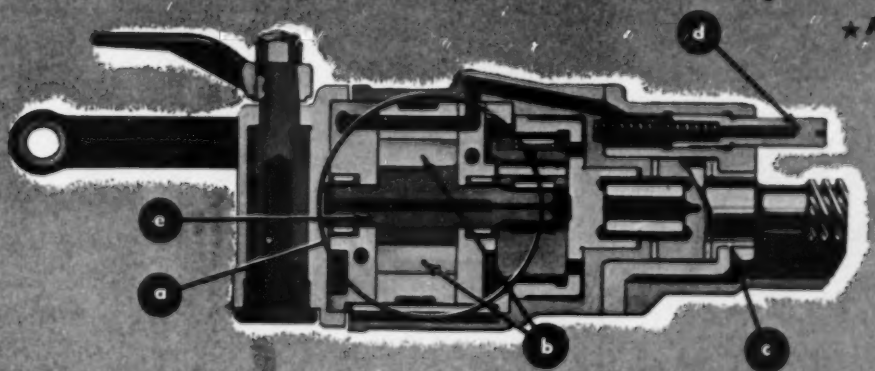
★ *Faster steel changes!* ★ *Constant rate of drilling!* ★ *Reduced operator fatigue!* ★ *More footage per shift!*



a. Motor proper is vane-driven, double-lobe type. Power is applied at diametrically opposite points of rotor — for better feeding action, more constant torque.

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e. One-piece rotor is carried on roller bearings at both ends. The three intermediate gears also operate on roller bearings.

RD-86

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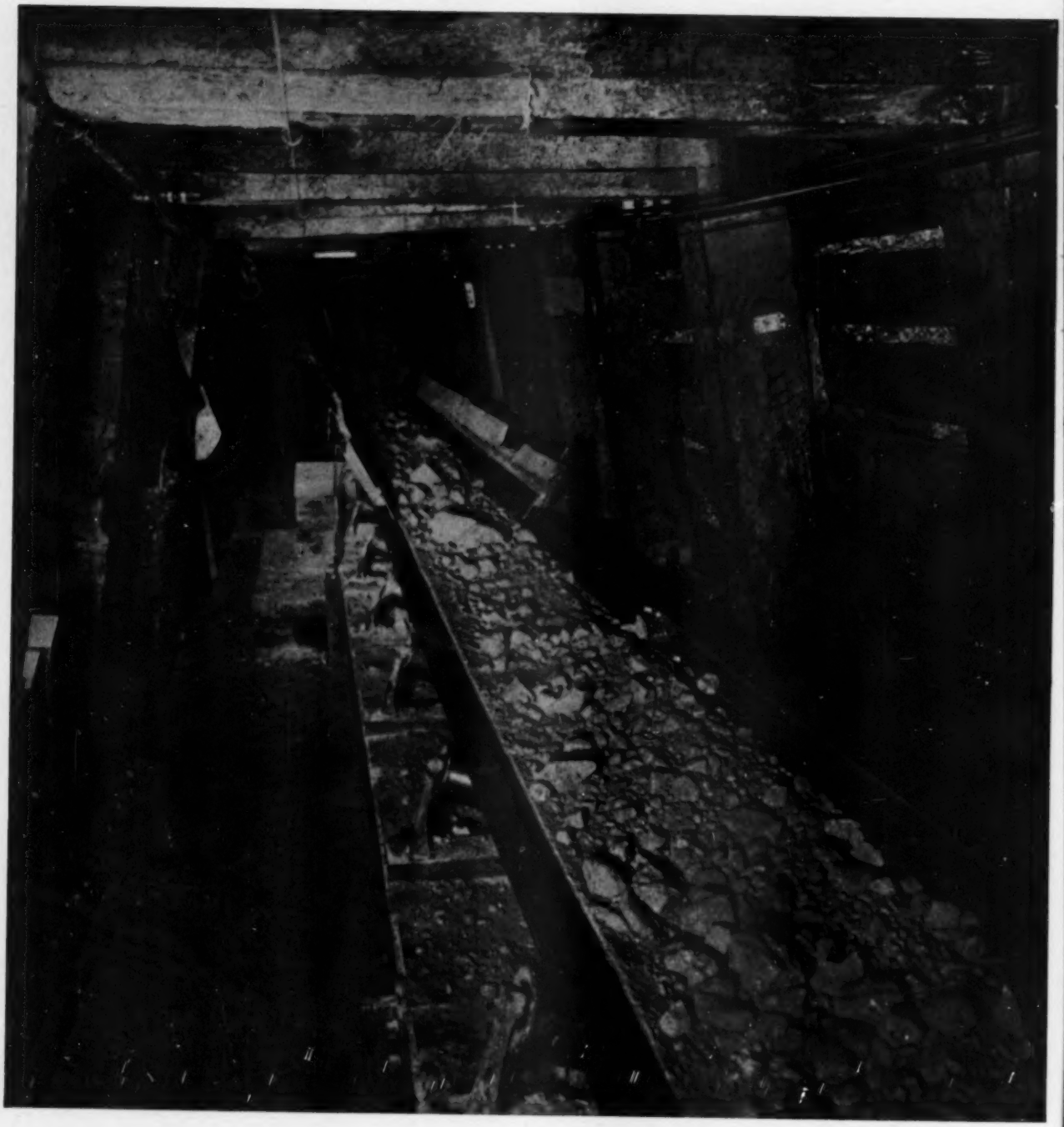

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EXECUTIVE OFFICES, STAMFORD, CONNECTICUT

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Whenever you handle ore in bulk—underground, overland, in open pit or mill—Hewitt-Robins belt conveyor systems will provide the most efficient, most economical answer.

Hewitt-Robins designs and manufactures a complete line of belt conveyor systems . . . Sectionalized Ore Mine —Mine-Type Shuttle—Engineered . . . each one matched to the requirements of a particular type of ore handling operation.

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FOR UNDERGROUND HAULAGE: Hewitt-Robins sectionalized ore mine conveyors and mine-type shuttle conveyors provide continuous transportation from working face to points of beneficiation. The mine-type shuttle conveyor answers the problem of truly continuous mining . . . it follows the working face and at the same time maintains a fixed transfer point through a fixed tripper—unit is extendable or retractable up to 600' . . . Sectionalized ore mine conveyors for main and stope haulage are available in 8' and 12' sections suitable for 3' and 4' idler spacing with choice of 24", 26", 30", 36", 42" and 48" belt widths.

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- Sand Blast
- Sand Suction
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- Servall®, All-Service
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Books for Engineers

Ore Deposits of the Western States, edited by the Committee on the Lindgren Volume, *American Institute of Mining and Metallurgical Engineers,* $7.00, 797 pp., fifth printing 1953.—Long out of print and consequently a rare item, this book was originally published in 1933. It is still the most comprehensive volume on one of the great mineral storehouses of the world. The list of contributors reads like a *Who's Who in Geological Literature.*

Metallurgy and Ceramics, Part I, A Bibliography of Selected Atomic Energy Reports of Interest to Industry, 38 pp., Oct. 1953.—Free copies available by writing *Industrial Information Branch,* U.S.A.E.C., Washington 25, D. C. Future announcements of AEC technical reports of interest to industry will appear in a special section of *Nuclear Science Abstracts,* issued twice monthly by the AEC, available on a subscription basis at $6.00 a year from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Metallurgical Dictionary, by J. G. Henderson, *Reinhold Publishing Corp.,* $8.50, 396 pp., 1953.—Over 5000 essential metallurgical terms alphabetically arranged, defined, and cross-referenced.

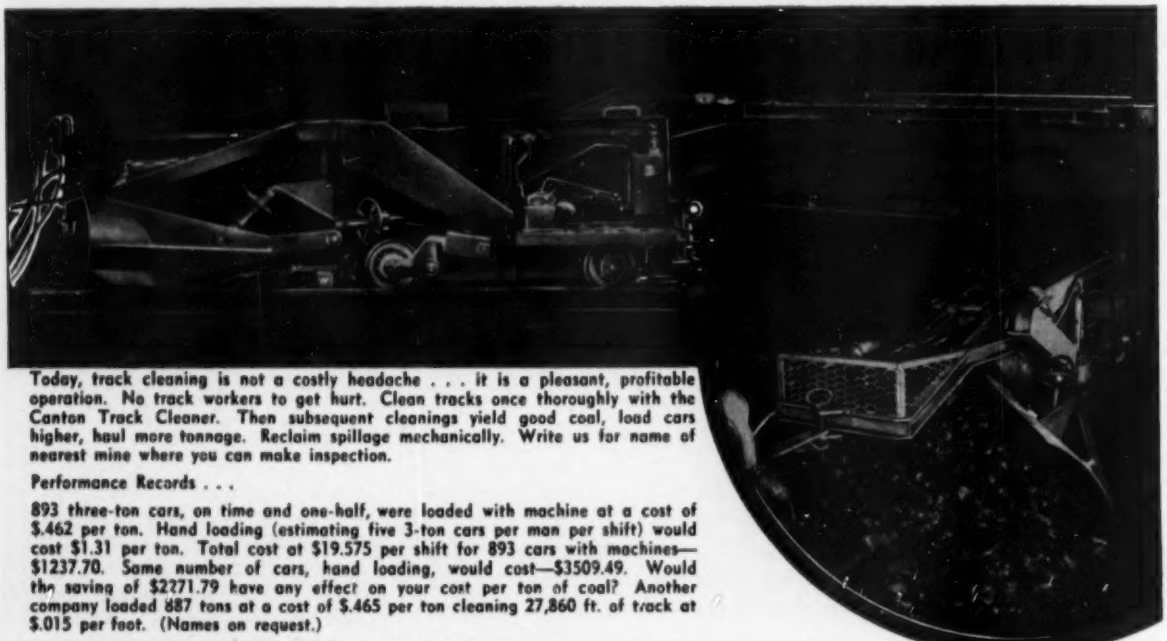
Geology of Australian Ore Deposits, A Symposium Arranged by a Committee of the Australasian Institute of Mining and Metallurgy, edited by A. B. Edwards, *Fifth Empire Mining and Metallurgical Congress,* Publications—Vol. I, about $12.00, plus postage, 1290 pp., 1953.—An informative volume that will serve as a basis for future geological study of Australia and also for the training of future geologists. Presented are 130 papers by 70 authors who are for the most part mine geologists or company consulting geologists. Where mineralogy is the outstanding feature, the author is the mineralogist most closely associated with the deposit.

Blazing Alaska's Trails, by Alfred H. Brooks, *University of Alaska* and the *Arctic Institute of North America,* $4.50, 517 pp., 1953.—Head of the U. S. Geological Survey in Alaska for 25 years, the author is a well-known Alaskan explorer, scientist, and historian. His record covers all phases of Alaskan life up to 1920. Included are ten chapters on Alaskan history, six on mining and the mining industry, one each on the flora, fauna, geology, geography, climate, native inhabitants, early transportation, fisheries, agriculture, education, and government in Alaska.

ORDER YOUR BOOKS THROUGH AIME—Address Irene K. Sharp, Book Department. Ten per cent discount given whenever possible. Order Government publications direct from the agency concerned.

Engineering Formulas & Tables, *Lefax Publishers,* Philadelphia, $2.75, 350 pp., revised.—Basic formulas, design data, and tables for civil, mechanical, and electrical engineers. Pocket-size, condensed, tab indexed. Sections include materials, hydraulics, reinforced concrete, pipe and fittings, steam tables, etc.

Richmond's South Africa All Mining Year Book 1953, edited by Johnson Richmond, *The Technical Map Service,* Johannesburg, approx. $9.00, 560 pp., with map in separate pocket, 1953.—A comprehensive record of mining and quarrying activities in the Union of South Africa, South West Africa, Swaziland, and Bechuanaland. Over 740 mining companies, syndicates or individual operators on more than 830 mines, quarries, and works, and some 90 metals and minerals are dealt with under 59 main headings. The accompanying map of the Union of South Africa and South West Africa locates every mine, property or works.



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893 three-ton cars, on time and one-half, were loaded with machine at a cost of $.462 per ton. Hand loading (estimating five 3-ton cars per man per shift) would cost $1.31 per ton. Total cost at $19.575 per shift for 893 cars with machines—$1237.70. Same number of cars, hand loading, would cost—$3509.49. Would the saving of $2271.79 have any effect on your cost per ton of coal? Another company loaded 887 tons at a cost of $.465 per ton cleaning 27,860 ft. of track at $.015 per foot. (Names on request.)

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Symposium on Tin, Presented at the 55th Annual Meeting ASTM, 1952, *American Society For Testing Materials,* Philadelphia, $2.50, 116 pp., 1953.—In the introduction Bruce W. Gonser states that tin is the only major common metal not covered by ASTM specifications. Because about half the tin consumed comes from metal cast in the U. S., cooperation has been promoted between users and producers to set needed standards. Among the papers included in this interesting symposium are "Tin Production and Resources," by F. Stuart Miller and "Effect of Impurities in Tin on the Properties and Uses of the Metal and Alloys Containing Tin," by C. L. Mantell.

The Van Nostrand Chemist's Dictionary, edited by Jurgen M. Honig and others, *D. Van Nostrand Inc.,* $10.00, 761 pp., 1953.—Definitions of some 11,000 terms in this semi-encyclopedic work vary from a few words to several paragraphs. Cross-indexed.

Protective Atmospheres, by A. G. Hotchkiss and H. M. Webber, *John Wiley & Sons Inc.,* $7.00, 341 pp., 1953.—Written especially for plant and process engineers, this book provides a concise survey of the properties, applications, generation methods, and results of atmospheric gases. Included are discussions of basic chemical reactions of gases used for furnace atmospheres and for preventing or reducing oxides.

Die Hebezeuge, Volume III: Sonderausführugen, by Hellmut Ernst, *Friedr. Vieweg und Sohn,* Braunschweig, Germany, approx. $11.00, 287 pp., 1953.—Vol. III of this series on hoisting equipment provides brief theory and thorough description of the characteristics of various specialized types: traveling workshop cranes; mill and floating cranes; mobile and railroad cranes; cableways; building and bridge cranes; composite materials-handling plants; weighing devices for hoisting equipment. Well-illustrated.

Symposium on Chemical Analysis of Inorganic Solids by Means of the Mass Spectrometer (Special Technical Publication, No. 149) *American Society for Testing Materials,* Philadelphia, $1.25, 35 pp., 1953.—Three papers deal with the following specialized aspects: determination of trace elements; analysis of solids with the high-frequency spark; analysis of copper for cuprous-oxide rectifiers.

Disrupted Strata, by M. H. Haddock, *Technical Press Ltd.,* London (distributed in U. S. by *Anglobooks*), third edition, $5.00, 104 pp., 1953.—A book "for the engineer connected with mining or water supply." Ways in which faulting may arise, major disruptions of the earth's surface, types of faults, and methods for determining the positions of disrupted strata are analysed.

Tonerde und Aluminium by Wilhelm Fulda and Hans Ginsberg, *Walter de Gruyter & Co.,* Berlin, **Volume 1: Die Tonerde,** approx. $6.50, 226 pp., 1951. **Volume II: Das Aluminum,** approx. $10.50, 385 pp., 1953.—In Vol. I the production of alumina from bauxite and from the aluminum silicates is dealt with in detail. The raw materials are discussed and the various processes are described with flowsheets, data tables, graphs. Vol. II covers metallurgical recovery of aluminum, its working, and fields of application. Special topics include aluminum electrolysis, manufacture of aluminum with electrolysis, secondary processes, casting aluminum and its alloys, scrap, and forming and surface treating procedures.

Theory and Practice of Structural Design Applied to Reinforced Concrete, by B. Eriksen, *Concrete Publications Ltd.,* London, approx. $5.50, 401 pp., 1953.—A book intended primarily to enable students to apply the principles of statics and the theory of elasticity to the design of structures for which formulas are not available. Part I is concerned with fundamental considerations and statically-determinate structures; Part II, with statically-indeterminate structures. Actual design procedure for a 90-ft portal frame bridge is appended.

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ORE DEPOSITS OF THE WESTERN STATES

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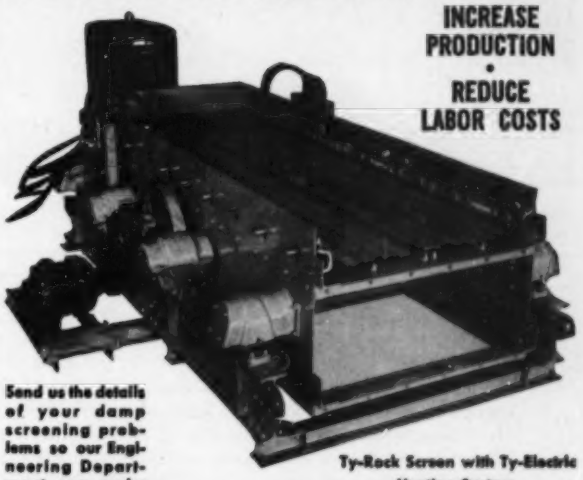

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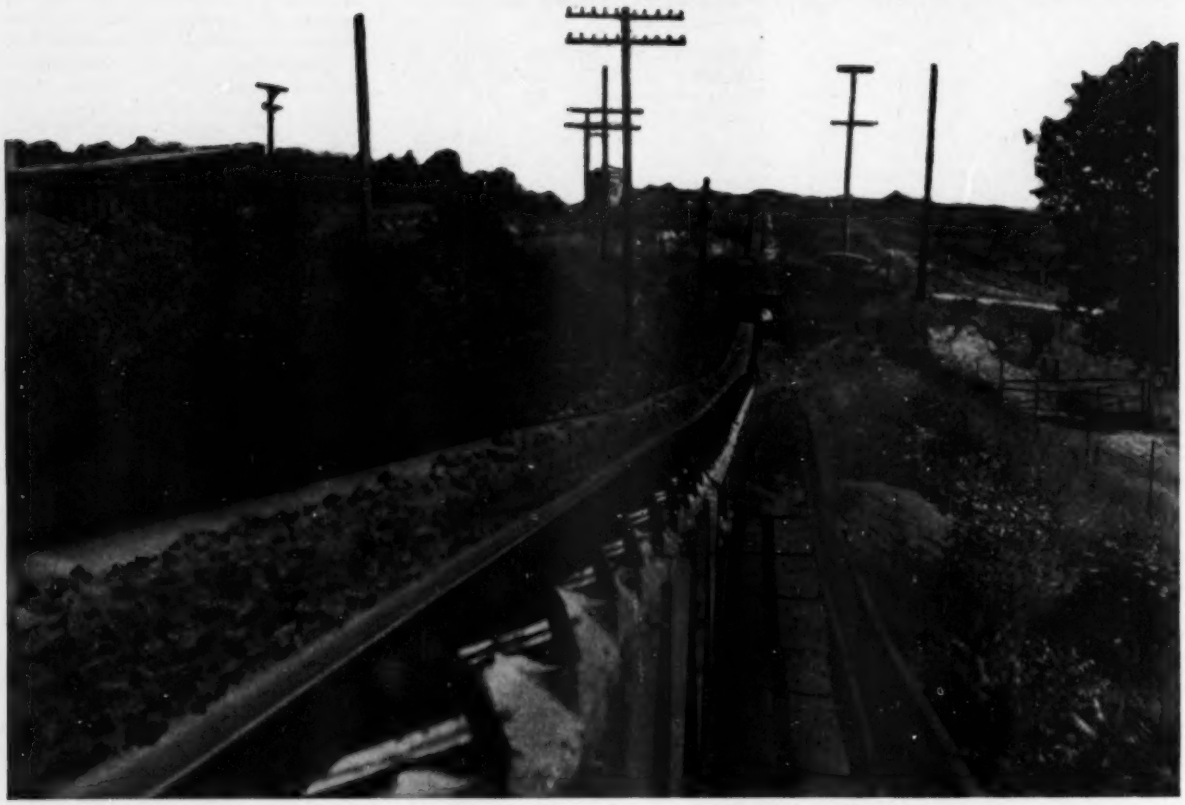


This is a U. S. Giant® Style XN Conveyor Belt—one of the tireless workhorses you'll find throughout the Mesabi Range. The excellent troughability is created by using Nylon in the transverse direction of the belt. This "U. S." Belt always trains easily, runs true, eliminates spillage.

LIKE all new developments, Taconite brings new problems for the mining companies—new problems for the manufacturers who must supply them with the right tools for the job.

United States Rubber Company has always been a pioneer in supplying materials for iron mining. The new Taconite processors can rely confidently on the fact that "U. S." will fulfill its requirements just as completely and faithfully.

Shown here are a few of the many products "U. S." makes for the iron mining industry. Each item is a *quality* product—the result of careful thinking and intensive work by "U. S." engineers who are specialists in the mining field. One example of "U. S." pioneering is the new U. S. Tailing Hose specially designed to handle iron ore tailings. In every instance, the goal of each of these products is to cut operating costs and thereby enable the operator to attain a good competitive position.

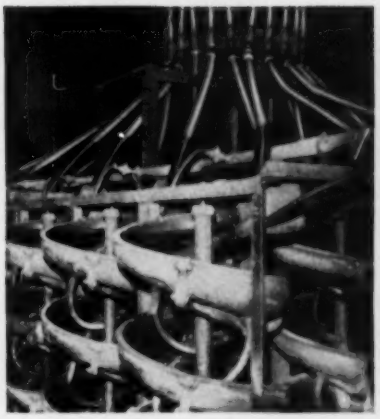
Leading mine officials can cut costs right from the start by buying from one source—and save time and trouble in the bargain. For fast, dependable delivery of United States Rubber Company products for the iron mining industry, order from your distributor or get in touch with one of the 25 "U. S." District Sales Offices.

Have you investigated the "U. S." three-way Engineering Plan? In three-way engineering, "U. S." engineers work hand in hand with the designers of the conveyor system and the engineers of the mine. This is a positive, fool-proof way of obtaining the *right* belt construction for the particular job.

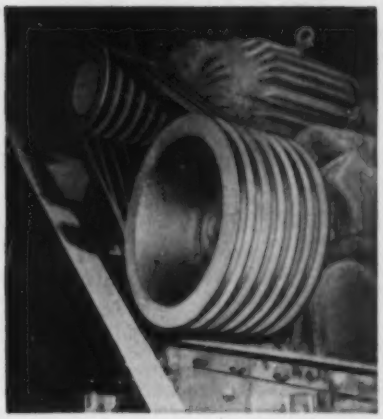
Iron Ore Mining

States Rubber Company

Ustex-Nylon belt by U. S. Rubber, installed on the Mesabi Range. 2,200 feet of this belt replaced 2½ miles of railroad track.



"U. S." small diameter hose and tubing play an indispensable part in iron ore separation. Above photo shows a section of a Humphrey Spiral equipped with "U. S." hose and tubing.



Matched set of six U. S. Rainbow® V-Belts which transmit power to a vibrating screen separator. These belts must withstand great shock loads from the vibrating action and must resist the action of abrasive particles which would damage ordinary belts.

U. S. Tailing Hose is designed as a flexible connection between the hopper and the metal pipe that conveys tailings to the processing plant. This hose withstands the abrasive action of the tailings, the high working pressures and the extremes of weather encountered all year 'round on the Mesabi Range.

U. S. Pilot® Flexible Pipe can run in a direct line from coupling to coupling—no need for elbows or short connections. Readily compensates for misalignment of pipe line and pump connection. Can be installed by unskilled crew in one-quarter the time for metal pipe, lasts far longer, weighs less. Will carry corrosive chemicals and solids such as Taconite, iron, coal and sand when suspended in water.

U. S. Royal® Shovel Cables are insulated with a high-grade rubber compound, and the conductor assembly is protected by a 60% neoprene sheath, vulcanized in lead for maximum density and ruggedness. Seven grueling laboratory tests, each of them tougher than actual conditions, guarantee U. S. Royal's resistance to moisture, abrasion, cutting, heat, cold, impact, flexing.

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"U. S." Research perfects it *"U. S." Production builds it* *U. S. Industry depends on it*

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Molded and Extruded Rubber and Plastic Products • Protective Linings and Coatings • Conductive Rubber • Adhesives • Roll Coverings • Mats and Matting

EIMCOS IN DRAWPOINTS FOR PRODUCTION LOADING

With more and more mining companies using drawhole systems adaptable to their properties new evidence supports the use of this method as the most practical and efficient means of fast development, efficient production and increased savings. Here are some of the important points to consider:

MECHANICAL LOADING	VS.	CHUTE AND GRIZZLY
After the entry is driven production can start immediately.	Development time.	Chute raises must be driven and timbered—grizzly must be developed then entry driven and production started.
Loading without spillage, ore drawn to haulage level.	Overall efficiency.	Loading with danger of spillage, ore drawn to grizzly level.
No lost time for repairs. Repair parts cost at approximately $.01 per ton loaded.	Operating maintenance costs.	Lost time for hang ups, lost time for chute repairs, cost of chute relining per ton varies.
100% salvage	Salvage value of equipment.	No salvage.
Safe working conditions, very little secondary blasting.	Safety.	Secondary blasting on grizzly level. Blasting in chutes to free clogged chute.

Add to these the advantages of loading cars full, easy operation even in wet places and a higher production per man shift. Write for information on many different mines that have changed to mechanical loading.

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You Can't Beat An Eimco

GM DIESEL
CASE HISTORY No. 534-130

USER: Preskitt Brothers Mines, Birmingham, Alabama

INSTALLATION: GM 3-71 Diesel powers Buckeye ¾-yard shovel stripping overburden and coal.

PERFORMANCE: Has worked 40 hours per week for 6 years—about 12,000 hours—with no repairs on engine. Uses about 2½ gallons of fuel per hour.

GM
GENERAL MOTORS
DIESEL POWER

Six Years' Tough Stripping

Not One Dime for Engine Repairs

S. O. Preskitt reports his men never laid a wrench on the GM Diesel powering this Buckeye shovel in 6 years of tough operation. It clocked approximately 12,000 hours stripping coal and overburden without a dime for engine repairs.

Sturdy, dependable General Motors 2-cycle Diesels deliver more power at less cost on all kinds of jobs. Two-cycle operation with power on every piston downstroke means faster acceleration, quicker response to controls, increased production. These smooth-running Diesels stay on the job day in and day out, but when service *is* needed, a phone call to your local GM Diesel distributor brings quick service and fast delivery of low-cost parts. Clean, simple design makes maintenance easy and economical.

Call your GM Diesel distributor today. Let him show you how to get more power at less cost in new equipment or in your present rigs.

DETROIT DIESEL ENGINE DIVISION
GENERAL MOTORS • DETROIT 28, MICHIGAN
Single Engines . . . 16 to 275 H.P. Multiple Units . . . Up to 840 H.P.

1200 FEET UNDERGROUND, iron ore moves to skip pocket on this S-A belt conveyor. S-A "Simplex" carriers have proven more than able to withstand the heavy loads and shocks of this operation. With an annual tonnage of about 300,000, this Menominee Range Mine in Michigan shows that the economies of underground haulage by belt conveyor are not limited to the handling of huge yearly tonnages. Additional conveyor flights are planned to complete the system.

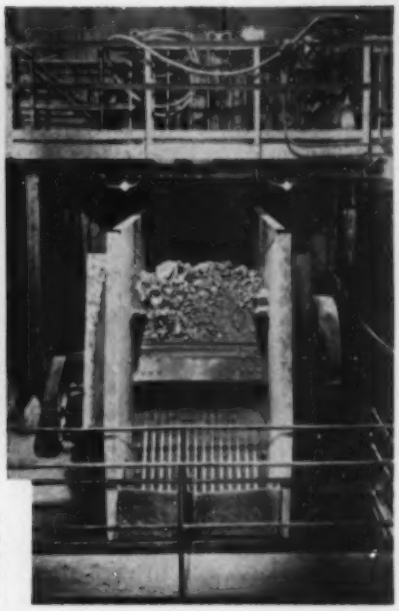
Low Cost Ore Handling Calls for Various Types of Conveying Equipment

When an S-A Conveying Engineer makes his recommendation, his choice of equipment is unlimited! This permits him to specify the type of system or equipment that will do any particular job most efficiently and economically. Drawing upon a complete line that includes every type of bulk materials handling equipment, he can be completely impartial.

What's more, he is backed by an engineering staff whose more than 50 years of experience covers just about every imaginable ore handling problem.

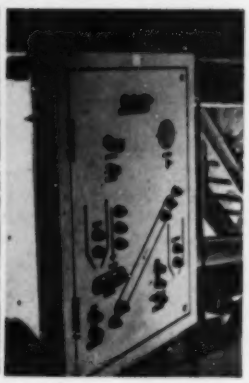
Whether or not *your* conveying needs are similar to any of those illustrated here, the chances are S-A has already met and solved a bulk handling problem *like* yours. Why not find out how we can help you by asking for a free survey. There's no obligation of course.

OVER 120 MILLION TONS of copper ore have been handled since 1939 by this 1412-foot S-A belt conveyor in Chile. The conveyor is still going strong, moving ore at the rate of 4800 tons per hour. More than 2500 S-A "Mammouth" and style "444" belt carriers have been in operation at this plant for more than a quarter of a century. All of them are in the multi-million ton class! In all, more than six miles of conveyor belts ride on S-A carriers at this plant.



DOUBLE-DUTY S-A CONVEYING SYSTEM handles two kinds of ore in alternating runs at this British Columbia mine. An S-A "AMSCO" plate feeder (see inset) receives lead-zinc ore from the chute at right, tungsten ore from the chute at left. Both ores are then carried by S-A belt conveyors to a transfer point outside the mine. Tungsten ore is shunted to another belt conveyor and carried to the tungsten mill. Lead-zinc ore is taken by a series of conveying flights to a mill in the valley. This system has eliminated the use of an aerial tramway and a fleet of trucks.

MORE THAN 4,000,000 TONS OF CRUSHED COPPER ORE have been handled since 1948 by this S-A "AMSCO" feeder and belt conveyor system in Arizona. The crushed ore drops 62 feet from the primary crusher to the heavy-duty manganese steel feeder. It is then discharged to an S-A belt conveyor which carries it to storage bins. Above the bins an S-A traveling tripper discharges the belt, insuring uniform loading of the bins. The system handles an average of 700 tons of ore per hour.



AUTOMATIC "TRAFFIC CONTROL" on this S-A conveying system helps move potash ore in high volume 900 feet underground near Carlsbad, N. M. An electric control system complete with panel that flashes a full picture of the conveying operation, makes sure that no unit feeding another can operate under load unless the unit ahead is running.

SINCE 1901 S-A STEPHENS-ADAMSON MFG. CO

STEPHENS-ADAMSON MFG. CO.

37 Ridgeway Avenue, Aurora, Illinois • Los Angeles, Calif. • Belleville, Ontario

Engineering Division
Specialists in the design and manufacture of all types of bulk materials conveying systems.

Standard Products Division
A complete line of conveyor accessories including centrifugal loaders—car pullers—bin level controls—etc.

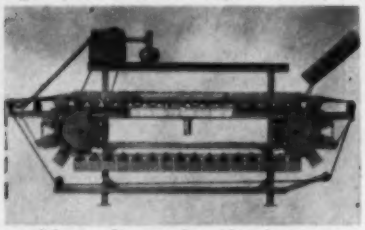
SealMaster Division
A complete line of industrial ball bearing units available in both standard and special housings.

Manufacturers News

New Products • *FILL OUT THE POSTCARD FOR MORE INFORMATION* • Equipment

Tray Belt Filter

Hardinge Co. announces a new type continuous, dewatering filter designed for fast filtering material, for



washing salts, or for filtering coarse sand or material devoid of supporting slimes. The Tray Belt filter consists of a series of connected, traveling, perforated trays in sliding contact with a suction box beneath and supporting a filter cloth which moves with but is not attached to the trays. Filter is gravity fed at one end, and cake discharges at other. Washing may be combined with filtration, and countercurrent flow can be obtained with a sectionalized suction box. **Circle No. 1.**

Bantam Cranes

Concentrating on one size, the ⅜-yd, 5 to 6 ton rig, *Schield Bantam Co.* now has a heavy duty crane carrier providing the Bantam purchaser a choice of mounting: on crawlers, remanufactured trucks, the customer's own truck, or the new carrier. **Circle No. 2.**

Mine Hoists

U. S. representatives of ASEA of Sweden, oldest electric company in northern Europe, is *Aros Electric Inc.*, a wholly owned subsidiary. Advantages claimed with multiple rope

ASEA hoists as compared with conventional cylindrical drum hoists are: increased safety, less rope wear, less weight and volume, lower peak power demand, lower power consumption. **Circle No. 3.**

Vibrator

Cleveland Vibrator Co. has developed a portable vibrator, type HCRR, for unloading railroad cars. Equipped with a hydraulically operated mounting clamp, the air vibrator can be quickly attached to a railroad car, bin, chute, hopper, or other handling device. **Circle No. 4.**

Stop Fires Fast

Brand-new air pressurized dry chemical fire extinguishers announced by *American-LaFrance-Foamite Corp.* go to work when you pull a pin and press the lever. The gadget-free Alfco extinguishers can be left partially discharged without loss of air pressure should a fire reflash before they can be recharged. **Circle No. 5.**

Fork to Dumper

Rotary dumping mechanism from *Automatic Transportation Co.* slips onto forks of the Automatic FF-15

industrial truck to give 190° forward rotation in dumping, adds versatility for handling small size materials. **Circle No. 6.**

Tractor-Shovel

Performance of the HM Payloader tractor-shovel has been improved by addition of hydraulic torque converter, according to the *Frank G.*

Hough Co. Also used in the HM Payloader tractor, the 3-element converter reduces clutching and shifting, easing strain on driver and power train alike. **Circle No. 7.**

Rectifier Speed Control

Variable voltage power drive for adjustable speed service is supplied by mercury rectifier, Xatron V-S drive from *Reliance Electric & Eng. Co.* Wide speed range is provided by package pre-engineered drive with control station, motor, and control unit. **Circle No. 8.**

Theromocouple Well

Metal-ceramic theromocouple well from *Bristol Co.* features reduced time lag, high strength, and shock resistance. **Circle No. 9.**

Rugged Roofing

Improved enameled steel roofing and siding, V-Corr marketed by

Toledo Porcelain Enamel Products Co. has a steel corrugated base with a fused porcelain enamel for complete protection again corrosion. **Circle No. 10.**

Conveyor Cover

Resistance to abrasion and tearing never before attained are promised by XDC conveyor belt cover developed by *Raybestos-Manhattan Inc.* Emphasis on cover as key to life is result of findings by Raybestos-Manhattan engineers that, "belt cover tensile strength has long been overemphasized . . . most failures are due to cover wear resulting in exposure of internal strength members and deterioration of entire belt." **Circle No. 11.**

Crane Carrier

One-man type crane carrier introduced by Crane Carrier Div. of *Cook Bros. Equipment Co.* incorporates independent 100 hp engine for travel and swing. Elimination of power transmission between crane and carrier is said to reduce necessary mechanism, reduce maintenance, and ease overhaul. **Circle No. 12.**

New Shovels

Two new ¾-yd power shovels in crawler and truck-mounted types,

become largest models in the Michigan Power Shovel line, recently acquired by *Clark Equipment Co.* **Circle No. 13.**

Hot Handling

Conveying hot or abrasive materials? *Goodman Mfg. Co.* offers line of shaker conveyors for distances to 500 ft up or downgrade, capacity to 100 tph, and in trough sections 12 to 36 in. wide, 6 to 16 ft long and 6 to 18 in. deep. **Circle No. 14.**

Free Literature

(21) KITS & SHOVELS: The 1953 fall catalog from *Thew-Lorain* lists part kits for modernization, conversion, or replacement of major assemblies and sub-assemblies. A catalog on the 2-yd Lorain Model 820-K shovel crane and a booklet on the 1-yd Lorain "50" are also available.

(22) MINE FANS: Adjustable-pitch fans for cooling tower, heat exchanger, and mine use are described in bulletin A-111 from the *Hartzell Propeller Fan Co.* This line includes 10 to 22-ft diam models with Hartzite (fabric-base) plastic blades and welded steel hubs, and 40 to 103-in. diam models with cast-aluminum alloy blades and hubs.

(23) RARE METALS: Optimum machining conditions of tungsten, molybdenum, tantalum, titanium, and zirconium are presented in a booklet from *C. Tennant, Sons & Co.*

(24) HANDLING DEVICES: A brochure from *American Forge & Mfg. Co.* pictures Cranehand automatic mechanical handling devices which allow a craneman to grip, lift, transport, and release loads by himself.

(25) INSULATION: *American Gilsonite Co.'s* folder shows how Gilsulate is poured around pipes exposed in trenches. In contact with hot pipes Gilsulate forms a triple zone of insulation said to provide permanent thermal insulation and corrosion protection.

(26) ROOFING & SIDING: Maintenance-free characteristics of aluminum roofing and siding for industrial buildings and shops are pointed up in a booklet from *Alcoa* that details methods of application. Also shown is an insulated industrial wall made from a sandwich of two layers of corrugated aluminum with a center of insulating material.

(27) GLASS BLOCKS: *Pittsburgh Corning Corp.'s* "P. C. Glass Blocks for Industrial, Commercial, and Public Buildings," is designed to be a reference manual for architects, engineers, and contractural personnel.

(28) SNOW REMOVAL: A catalog from *National Lift Co.* illustrates how more than 10,000 Snowlift users have averaged savings of $100 per plow, per season in their snow removal programs.

(29) AIR SAMPLER: To solve the problem of air pollution, industry, Government, and medicine must know what particles are in the air. A folder from the Air Sampler Div.,

Staplex Co. presents quick facts about the Staplex high volume air sampler which was developed in the laboratories of the New York office of AEC and is now available for general use.

(30) PRECISION BALANCES: Bulletin No. 329 from the *Burrell Corp.* furnishes the scientific field with information on Stanton balances, English-made line of precision chemical and nonchemical balances. The four models, pictured and described, fit a variety of laboratory needs and uses.

(31) CARTRIDGE TOOL: *Velocity-Power Co.'s* Model P driver is a power-actuated tool for driving steel studs into steel, concrete or masonry. Approved by Underwriters' Laboratories Inc., the driver has a safety arm that prevents accidental discharge when the tool is set aside or dropped.

(32) HELPFUL SHORT CIRCUIT: Famous as a trouble maker, the short circuit has been harnessed by *General Electric* and put to useful work. GEA-4053B explains step-by-step the electrical principles of amplidyne systems, describes and illustrates applications.

(33) HEAT MEASUREMENTS: Catalog No. 85 from the *Pyrometer Instrument Co.* not only gives detailed information on the Pyro-optical pyrometer, but also features technical information on the principles of optical pyrometry.

(34) WATTS IN ZULULAND: "Onan on Safari," published by *D. W. Onan & Sons Inc.*, is Commander Attilio Gatti's story of his 12th African expedition. The noted explorer and movie producer carried with him four Onan electric plants to operate not only stage lights, arcs, spots, but five refrigerators, an electric typewriter, dictaphones, insect electrocuting screens, and scores of other appliances and gadgets.

(35) LINATEX BALL MILLS: Widely used for abrasion resistance, Linatex finds new application in ball mills completely lined with rubber. Unusual construction of the mills which range in size from 12 to 42-in. in diam is described in booklet from *Linatex Corp. of America.* Extensively used in England, units pulverize variety of pigments, chemicals, and ceramics.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after May 15, 1954—if mailed in U. S. or Canada

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61	Students are requested to write direct to the manufacturer.								

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Company_____

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(36) ROCK BITS: Astounding increases in drilling production and savings in costs are claimed for drill bits treated with Hard-N-Tuff in "Is Your Problem Rock?" Folder from *Doughty Laboratories* outlines easy application of this hardening compound for rock bits and churn drills.

(37) TRACK-TYPE TRACTOR: Form 30379 from the *Caterpillar Tractor Co.* is a 32-page booklet with photographs and model cutaways of the basic components of the D6

track-type tractor. In addition to a specification sheet and attachment list, there are suggestions for other equipment that may be used with the D6 tractor.

(38) SPRAY NOZZLES: *Spraying Systems Co.'s* catalog No. 24 contains 48 pages illustrating and describing thousands of standard and special industrial spray nozzles.

(39) FROZEN COAL? Formula 5 is a 30 to 70 mesh dry product containing sodium chloride, combined with a corrosion inhibitor and chemically treated to produce a free flowing material. "Freezeproofing Coal From Test Tubes" from the *Morton Salt Co.* explains and illustrates the whys and wherefores of coal freezeproofing with Formula 5.

(40) WIRE ROPE: Stretching the life span of wire rope is the subject of "Wire Rope — Use and Abuse" issued by *E. H. Edwards Co.* Illustrated with photographs, technical drawings, and diagrams this two-color booklet contains sections dealing with handling, installing, storing, and lubricating.

(41) GAMMA RAY DETECTOR: *Radiac Co. Inc.* has literature on the new model 963 Scintillometer which weighs only 7 lb with batteries.

(42) EVERYBODY SELLS: In "The Extra Touch" the *Bureau of Business Practice* advises that every employee influences the sales of his firm's products whether he makes a screw or bolt, works on a lathe or an adding machine. Slipshod work loses customers and cuts production. Men are laid off; profits vanish.

(43) LUBRICATION: Comparisons of methods for lubricating electric motors are depicted in a bulletin issued by *U. S. Electrical Motors Inc.* Illustrated are the three principal types of bearings used in motors —cartridge, standard open, and U. S. Lubriflush types—with explanations of each.

(44) PLASTIC SHEETS: A 12-page catalog describes and illustrates application of clear cast thermoset "Cocor" sheets made by *Cast Optics Corp.* Unusual properties such as high abrasion and heat resistance, toughness, and complete solvent resistance are featured. Technical properties and fabrication data are included.

(45) RIPS-ROOTS-DOZES: Claimed to be quickly and easily attached to any heavy duty dozer, the Esco Dozer-Rooter adjusts to four rooting depths and can be attached or detached by one man. Made by the *Electric Steel Foundry Co.*, the Dozer-Rooter "is designed to dig itself in, thus making maximum use of tractive power."

(46) CORROSION DATA: "Corrosion Resisting Properties of the Austenitic Chromium-Nickel Stainless Steels" is a 32-page bulletin from *International Nickel Co. Inc.* Eighteen tables show the results of tests on numerous stainless steels in various solutions, acid, neutral, and alkaline.

(47) SPLICING: *B. F. Goodrich Co.* has a 32-page, illustrated handbook on splicing rubber transmission belts with the Plylock belt joint. According to Goodrich, nine out of ten transmission belt failures are caused by belt fastener trouble. The BFG Plylock belt joint is said to end separation by creating a strong yet flexible joint without butted outside plies that open at the surface and gradually pull apart.

(48) POWER TRANSMISSION: A 4-page brochure from the *Lovejoy Flexible Coupling Co.* features flexible couplings, variable speed pulleys, transmissions, and universal joints.

(49) EARTHMOVING EQUIPMENT: "The Co-Operator" is a magazine for equipment operators, mechanics—for anyone who is interested in earthmoving equipment. Its readers are kept informed of *LeTourneau-Westinghouse* equipment developments, applications, and recommended operating and maintenance practices.

(50) REAGENT PROBLEM: Armour Chemical Div. *Armour & Co.* produces a wide range of fatty acids

and fatty acid derivatives—anionic and cationic reagents for flotation. If you have a separation problem Armour may be able to supply the answer.

(51) MOLYBDENUM: Sprabond wire, pure molybdenum in form for metallizing, is covered in bulletin from *Metallizing Engineering Co.* Use for bearing surfaces, and direct application to aluminum and magnesium alloy parts are pointed out in addition to use as bonding coat.

(52) SILICON CARBIDE: In a 52-page brochure, the *Carborundum Co.* discloses the properties of silicon carbide, outlines manufacturing techniques, and discusses applications in the fields of refractories, heating elements, resistors, as a deoxidizer, as a catylist carrier, and as a porus media. A bibliography is also included.

(53) SURVIVAL STORY: *American Cyanamid Co.* has a reprint describing the coal preparation plant of the Wise Coal & Coke Co. "Coal Preparation with New Type Heavy-Media Operation" is the "story of one coal company's efforts to stay in business by improving its products through better preparation."

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has paced the progress of AMERICA

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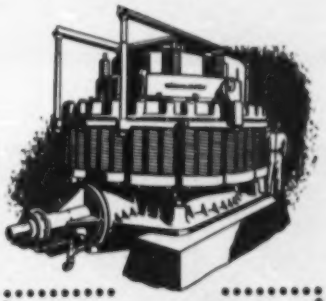
In the great agricultural lands of America, limestone has long been recognized as an invaluable aid to raising better crops . . . as well as an important mineral supplement in poultry and animal feeding. In the building of the modern cities of today, limestone has paced America's progress by making possible better roads and streets, building stone, cement, steel for building and transportation, glass . . . and hundreds of other materials and products that are woven into the pattern of modern civilization.

With man's continual expansion of the number of uses of limestone, and ever-increasing refinements in specifications, the problem of rapidly furnishing properly sized stone to meet today's requirements has become more difficult. Symons® Cone Crushers have become the answer to scores of these problems, and as a result, hundreds of Symons Cone Crushers . . . in both Standard and Short Head types . . . have been installed by most of the leading producers of crushed limestone throughout the world.

Thus, in limestone operations . . . *as in all of the great ore and industrial mineral operations the world over* . . . SYMONS Cone Crushers are relied upon to efficiently produce great quantities of finely crushed product at low cost.



SYMONS Cone Crushers . . . *the machines that revolutionized crushing practice* . . . are built in Standard, Short Head, and Intermediate types, with crushing heads from 22 inches to 7 feet in diameter—in capacities from 6 to 900 tons per hour.

C383

NORDBERG MFG. CO., Milwaukee, Wisconsin

SYMONS . . . A REGISTERED NORDBERG TRADEMARK KNOWN THROUGHOUT THE WORLD

NORDBERG

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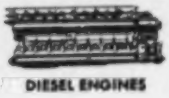
SYMONS GYRATORY CRUSHERS

GRINDING MILLS

SYMONS "V" SCREENS

SYMONS VIBRATING BAR GRIZZLIES and SCREENS

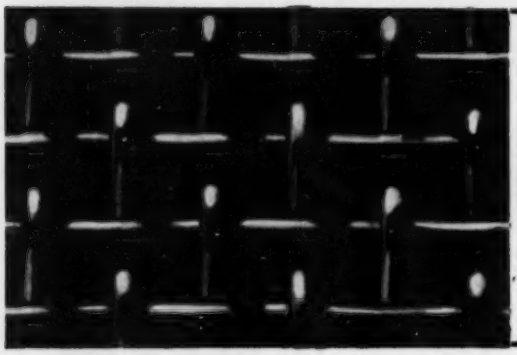


DIESEL ENGINES

CF&I STEEL PRODUCTS for

WICKWIRE ROPE

Over 125 years of experience in the manufacture of wire and wire products stands behind Wickwire Rope. It is made from wire with the maximum degree of hardness, strength, toughness and fatigue resistance. Quality controls, through the manufacturing process, assure the utmost in performance, safety and long life.



CAL-WIC INDUSTRIAL SCREENS

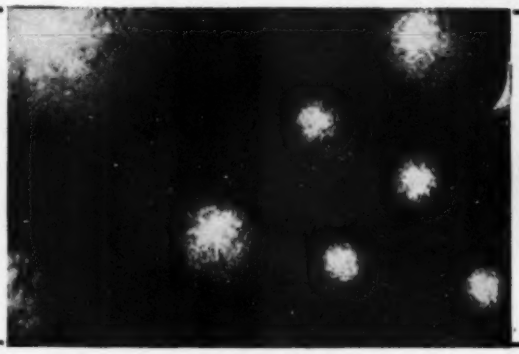
For every screening operation there is a Cal-Wic Screen that will give maximum output of the desired product with minimum wear. They are woven to the most exacting tolerances for the greatest efficiency.

CF&I ROCK BOLTS

This modern means of mine roof or wall support provides greater safety, economy and better housekeeping. Slot and wedge type, as illustrated, or expansion shell type.

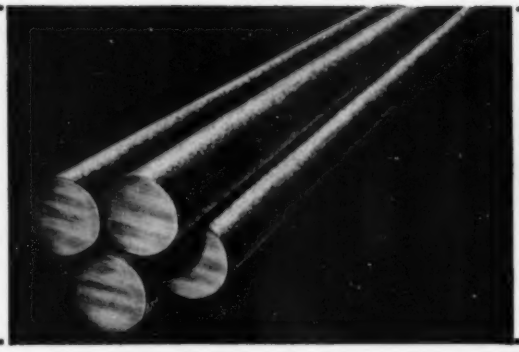
From ore to finished product . . . CF&I mining specialties are products of a completely integrated operation. They are manufactured to the high standards of quality recognized by the mining industry.

MINING'S GREATEST ERA



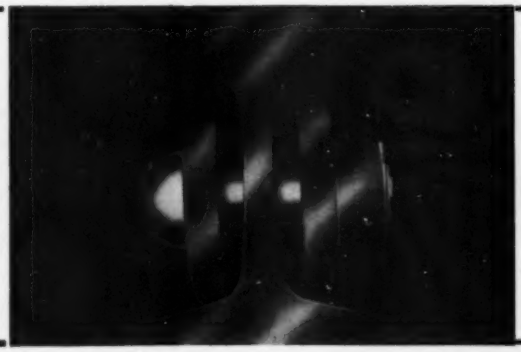
CF&I GRINDING BALLS

CF&I Grinding Balls are forged from special analysis steel to give high impact and abrasion resistance . . . the balance between toughness and hardness insures greater through-put, even wear and high efficiency.



CF&I GRINDING RODS

Rolled from special analysis steel for efficient, economical grinding. Machine straightened with square cut ends. Equally effective for Fine Crushing or Coarse Grinding.



CF&I MINE RAILS & ACCESSORIES

Made to A.R.A. standards; available in a range from 12 to 45 pounds. Accessories include splice bars, angle bars, spikes, track bolts and nuts—square or hexagon.

1700

THE COLORADO FUEL AND IRON CORPORATION • Denver, Colorado

WICKWIRE SPENCER STEEL DIVISION • New York, New York PACIFIC COAST DIVISION • Oakland, California

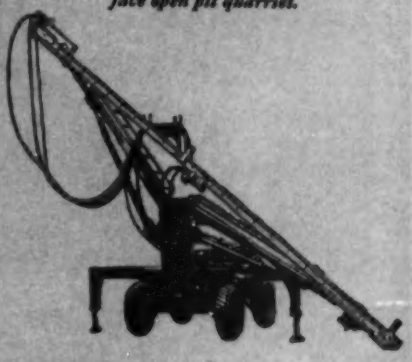
THE COLORADO FUEL AND IRON CORPORATION

CF&I

The World's Most

Joy DM-2 Drillmobile, a self-propelled, rubber-tired unit.

Joy DM-10 Drillmobile designed for drilling in high-face open pit quarries.



Joy Hydro Drill Jib mounted on the back of a truck, drilling blast holes in high-faced underground quarries.

Large tunnel Jumbo drilling top heading—mounts 17 Joy drifters on Hydro Drill Jibs.

Special wide-frame Joy Drillmobile drilling down holes on a dam construction job.

Joy Hydrojib Pipeline Drilling Rig with two Hydro Drill Jibs and built-in air compressor.

Versatile Drill Mounting...

JOY HYDRO DRILL JIBS

Here's the drill mounting that puts your drill just where you want it—easily and quickly. Field-proved for more than ten years under practically every mining and tunneling condition, the Hydro Drill Jib is now recognized as the standard for mechanizing drilling practices.

Look at these other proved advantages which make the Hydro Drill Jib outstanding in the field:

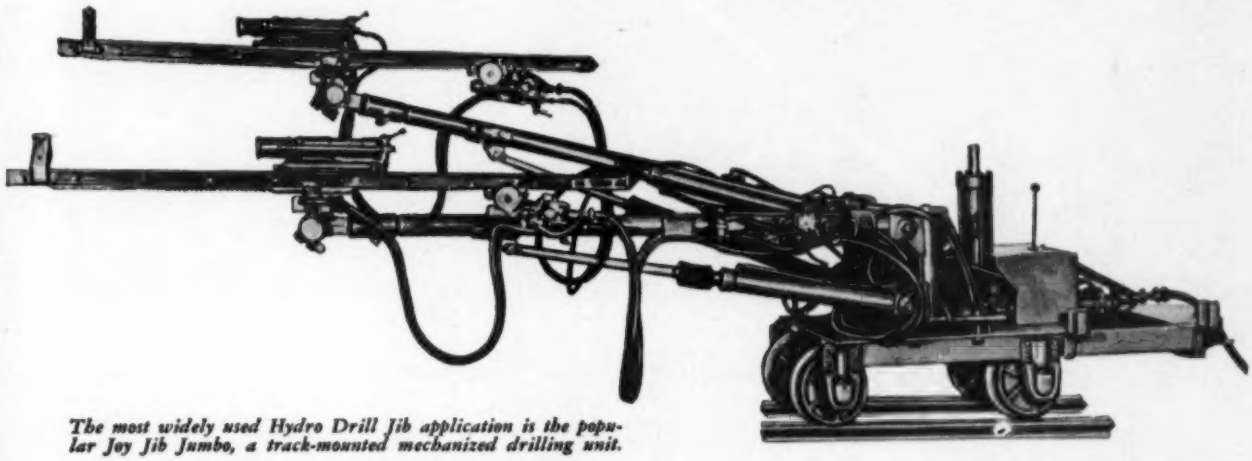
- More accurate hole spacing
- Fewer steel changes with long chain feeds
- Greater flexibility

The versatility of the Hydro Drill Jib is illustrated in the variety of mountings shown here.

One of these may be the one you need for your special drilling problems.

If you don't see the answer here, Joy can supply it with some other adaptation of the versatile Hydro Drill Jib.

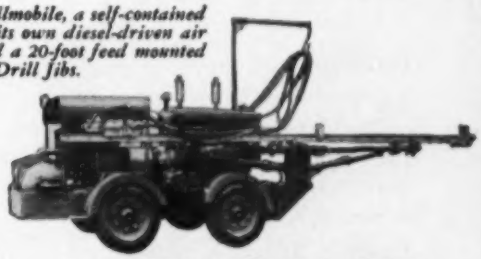
Joy Manufacturing Company, Oliver Building, Pittsburgh 22, Pa. In Canada: *Joy Manufacturing Company (Canada) Limited, Galt, Ontario.*



The most widely used Hydro Drill Jib application is the popular Joy Jib Jumbo, a track-mounted mechanized drilling unit.

Joy DM-8 Drillmobile, a self-propelled unit developed for mine roof bolting.

Joy DM-4 Drillmobile, a self-contained unit carrying its own diesel-driven air compressor and a 20-foot feed mounted on two Hydro Drill Jibs.



Special Joy Drillmobile with electric motor drive for tramming.

Consult a Joy Engineer

JOY

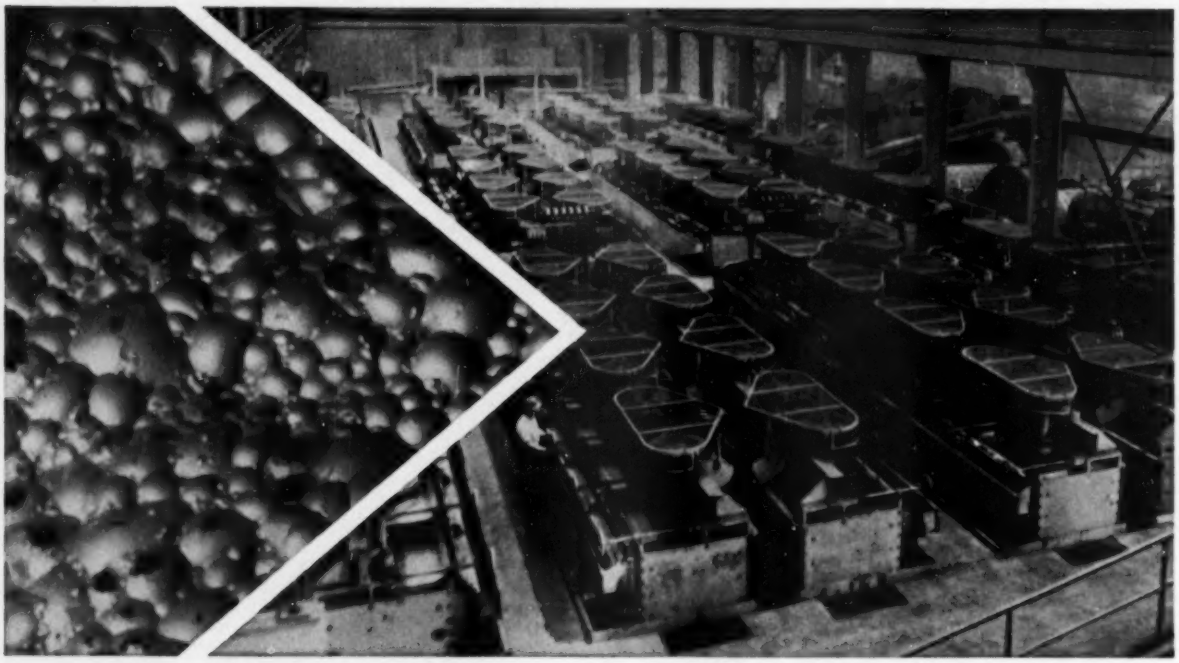
WBD M-4939

WORLD'S LARGEST MANUFACTURER OF UNDERGROUND MINING EQUIPMENT

DOW

DOWFROTH 250

BUILDS BETTER FROTH AT LOWER COST



This quality frothing agent by Dow raises concentrate grade and increases recovery —with less frother consumption!

Dowfroth® 250 in many mills today is producing improved metallurgy with as little as one-fourth the consumption of previous frothers used. These are not just laboratory tests, but full-scale mill results. This could mean increased profits and lower operating costs in *your* mill, too.

Dowfroth 250 is easy to use—requires minimum conditioning for stage addition. Its water solubility permits accurate regulation as a water solution if you prefer this method. And it demonstrates little or no collecting power, which allows your operator to regulate frother and collector independently. This hard-working frother by Dow also spares the rubber covered parts on your flotation machines—shows minimum swelling and deterioration to save you money in maintenance.

Prove the economy and efficiency of Dowfroth 250 in your own mill by using a test sample with our compliments. Write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. OC 834I.

you can depend on DOW CHEMICALS

DOW

ENGINEERING SIDELIGHTS OF THE EMPIRE STATE BUILDING:

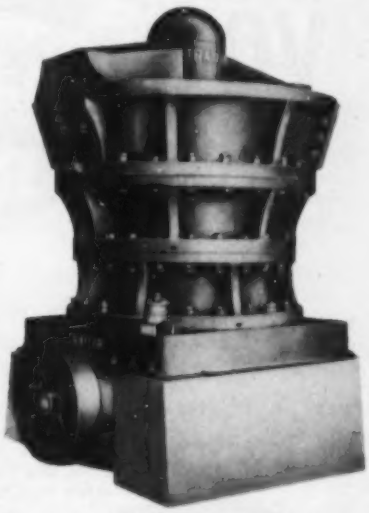
Construction of the world's tallest building in 1931 was so well coordinated that builders erected 10,000 tons of steel per month in the heart of busy Manhattan without blocking traffic in the City's streets. After the first six floors, workers raised steel at the rate of one floor per day until completion of this 1,250-foot, 102-story skyscraper. Perfect planning and smooth teamwork made this a truly outstanding example of modern engineering achievement.

Modern Construction Demands Improved Materials

For over half-a-century Traylor Engineers have worked closely with industry in creating equipment that's "TRAYLOR-MADE" to produce better materials . . . materials that continue to keep pace with increasingly exacting demands of advanced engineering practices. The Traylor TC Gyratory Crusher is a *modern* example of this coordinated teamwork. You'll find sound engineering proof of this in Traylor Original Curved Concaves and Bell Heads. These Curved surfaces apply power efficiently as a direct crushing force to reduce lifting and churning of material in the crusher. Choking and packing are practically eliminated because each zone in the crushing chamber has greater capacity than the preceding zone . . . reduced material has free fall from the discharge end. These achievements of Traylor Engineering assure a more uniform product to meet the constant demand for better materials. Traylor bulletin 126 gives complete specifications for all Traylor Gyratory Crushers. Send for your free copy today.

Traylor's Big 60" TC Gyratory has the Capacity to reduce 303,000 tons of material (weight of the entire Empire State Building) in less than 106 hours.

Traylor TC Gyratory Crushers are built in seven sizes with feed openings from 20" x 80" to 60" x 210".



TRAYLOR ENGINEERING & MANUFACTURING CO.
614 MILL ST., ALLENTOWN, PA.

SALES OFFICES: New York • Chicago • San Francisco
CANADIAN MFRS: Canadian Vickers, Ltd., Montreal, P. Q.

Primary Gyratory Crushers | Rotary Kilns | Secondary Gyratory Crushers | Ball Mills | Jaw Crushers | Apron Feeders

this costs money
Underloaded conveyors cost you money because they are not utilized to capacity . . . you're not getting full return on your investment . . . subsequent operations are starved for materials.
this wastes money
Overloaded conveyors cause unnecessary cleanup . . . thus waste labor. Subsequent operations are periodically flooded with more material than they can handle.
this saves money!
A properly loaded conveyor, with flow to it regulated by a Rex® Feeder, is economical and efficient . . . promotes smoothness and economy throughout entire processing operation.

YOU save time, material, money with REX apron feeders!

Uniform, Regulated Flow . . . that's important when you're concerned with moving bulk materials from bin or hopper to belt conveyor or crusher. With Rex Feeders you're assured a metered, uniform rate of transfer, regardless of variation in size of material handled. Your belt conveyor or crusher will receive a steady flow of material to assure smooth, efficient, low-cost operation.

Ask your Rex Field Sales Engineer to give you complete information on how you can save money with Rex Feeders. Call the office nearest you, or write to Chain Belt Company, 4794 W. Greenfield Ave., Milwaukee 1, Wis.

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EXPORT OFFICE: 4800 W. Mitchell St., Milwaukee 1; New York office: 19 Rector Street
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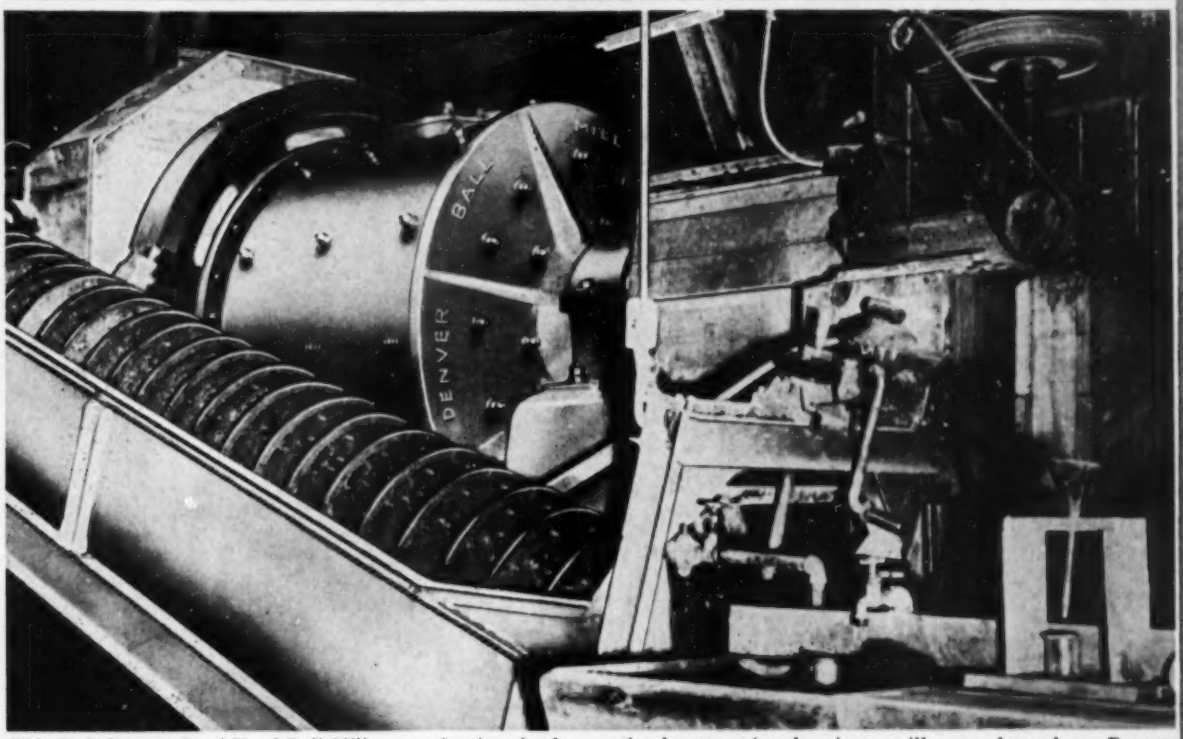
DENVER BALL-ROD MILLS

Complete Milling Equipment—from testing, to feeder, to dryer!



This 5'x5' Denver Steel-Head Ball Mill, operating in a lead-zinc, gold-silver mill, shows the heavily reinforced steel head. Because of the crack-proof Denver Steel Heads and the long-wearing bearings, mill men depend on Denver Ball-Rod Mills for years of service. A No. 250 Unit Flotation Machine is pictured on the right.

Eliminate Shut-Downs Caused By Cracked Heads, Use Denver Steel-Head Ball-Rod Mills

Many years of continuous, high production with minimum maintenance and repair are possible with Denver Steel-Head Ball Mills. Because of the specially constructed steel heads in all Denver Ball-Rod Mills, the danger of cracking a mill head has been eliminated. Steel is the best insurance against cracked heads and resulting mill shut-downs. Your profits are greater because of the dependable, continuous service you get from Denver Ball-Rod Mills.

CRACK-PROOF STEEL HEADS

By using tough steel, four times stronger than ordinary cast iron, not one Denver Steel Head has ever been reported cracked. The steel heads are electric welded to a steel shell, giving you all-steel construction throughout (bolted steel construction is also available).

MAXIMUM BEARING LIFE

Denver Steel-Head Ball Mills are completely assembled and then the trunions are turned in a big lathe, making trunions absolutely true and accurate.

This accuracy makes bearings wear longer because the weight is evenly distributed over the entire bearing surface — giving lower pressure per square inch of bearing surface. Evenly distributed wear permits efficient use of babbitted bearings and eliminates ball and socket joints.

Write or wire today. Find out how these and many other advantages of Denver Ball-Rod Mills give you more dependable service and increase profits.

Free Technical Bulletin Sent on Request

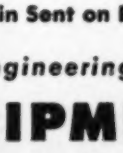
Over 25 years of Flotation Engineering

DENVER EQUIPMENT COMPANY

1400 SEVENTEENTH ST. DENVER 17, COLORADO

DENVER "SUB-A" FLOTATION

DENVER "SUB-A" SUPER ROUGHER FLOTATION MACHINE


DENVER SUPER AGITATOR AND CONDITIONER

DENVER "SUB-A" UNIT CELL

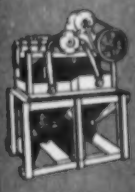
DENVER DIAPHRAGM PUMPS

DENVER DILLON SCREEN

DENVER DISC FILTER

DENVER JAW CRUSHER

DENVER STEEL HEAD BALL MILL


DENVER MINERAL JIG

DENVER VERTICAL PUMP

DENVER SRL PUMP

DENVER AUTOMATIC SAMPLER

DENVER STEEL HEAD ROD MILL

DENVER ORE FEEDER

Help for Mine Operators on the cost sheet... and on the job

In the past 15 to 20 years, the mining industry has kept stripping and output costs down in spite of rising labor and material costs. To do it, mine operators have pioneered new earth-moving techniques that have put constantly increasing demands on machinery. That's why in today's tough competitive era, mining requires modern, versatile equipment that enables the mine operator to increase output per man-hour and work at a profit.

In an effort to cooperate fully to meet these demands, Allis-Chalmers has for years geared its progress to that of the mine operator himself... now offers him completely new designs like the HD-15... a machine that takes advantage of even the most recent developments in tractor application.

The design of the HD-15 also makes full use of new metals, new oils and greases, and the latest manufacturing processes. Existing models were not allowed to restrict Allis-Chalmers engineers . . . so they worked right from the ground up, matching part to part, assembly to assembly, and the entire tractor to its Allied equipment. As a result, the HD-15 offers new standards in ease of operation and service, as well as long-life performance. With outstanding balance characteristics, it handles both mounted and drawn equipment well, provides maximum flexibility for the wide variety of jobs.

We invite you to talk with your nearby Allis-Chalmers dealer to compare values . . . see for yourself how the HD-15 can be a big factor in helping you to increase output per man and hold costs in line.

ALLIS-CHALMERS
TRACTOR DIVISION • MILWAUKEE 1, U. S. A.

HD-15
109 drawbar hp.
27,850 lb.
Six speeds forward to 5.8 mph.
Three reverse speeds to 4.5 mph.

Constant progress in earth-moving methods has been matched by such design advances as this HD-15 and its engine-mounted dozer . . . which were engineered and tested as a unit, right from the start.

This HD-15 Tractor Shovel is a tool which introduced a new era of tractor usefulness. This versatile machine moves from job to job easily and does traditional jobs in a better, faster way.

The improvements and refinements of really modern design take on new significance as demands on machinery grow. Extra yardage handled . . . or lubrication time saved means working more efficiently, more profitably.

Ni-Hard Resistance to Abrasion

The Benson Mines of Jones and Laughlin Ore Co., Star Lake, N.Y., estimate that these Ni-Hard liners will grind at least 2½ million tons of ore—which means 3 to 4 times better service than that obtained from manganese steel liners previously used. Cast by Plattsburg Foundry & Machine Co., Plattsburg, N.Y., an authorized producer of Ni-Hard castings.

After Grinding 2,000,000 tons of Iron Ore these Ni-Hard Liners are still in service

1,040,000 TONS OF ORE were ground during the first 14 months after installation of these Ni-Hard® liners. The photograph, taken at the end of that period, shows them to be in excellent condition. Actual measurement showed less than 10% wear . . .

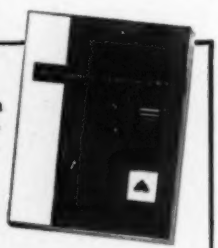
And after grinding more than 1,500,000 tons of ore, they showed total wear of about 25%. By comparison, liners of austenitic manganese steel were completely worn out after grinding 600,000 to 800,000 tons of ore.

Ni-Hard, a nickel-chromium white iron of moderate cost, is produced under foundry controls to meet INCO's high standards. Ni-Hard is obtainable from authorized foundries, coast-to-coast, in all shapes common to the foundry industry.

Call on our 20 years' practical experience in the Ni-Hard field to determine how this wear-resistant material will *stand the gaff* in your equipment.

The completely revised third edition of "Engineering Properties and Applications of Ni-Hard" is now available. Write for your copy today.

INCO



THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.

REPUBLIC STEEL CORP. signed an exploratory option with Pan American Commodities S. A., Lima, Peru, for the purchase of about 65,000 acres in Peru. The land is near the southern border of Peru, about 20 to 25 miles from the Pacific Coast. Donald B. Gillies, Republic mining consultant, stated after a visit to the potential iron ore area, said that indications are that the ore may run as high as 66 to 68 pct iron with extremely low water content. Republic emphasized that the agreement is simply to find out "what there is in the way of iron ore on the land."

CANADA'S MINERAL PRODUCTION jumped to $1.33 billion for 1953, an increase of 3.4 pct over the previous record of $1.28 billion set in 1952, according to preliminary statistics released by Dominion Bureau of Statistics. Value of metal output decreased 2.6 pct, reflecting lower base metals prices; mineral fuels increased 18 pct; and other nonmetallics went up 1.9 pct. Structural materials reached a new high value with a gain of 8.7 pct. Value of all metals was $709 million in 1953, compared with $728 million in 1952. Copper production was 2 pct less than in 1952 but higher prices prevailed.

Value of mineral production in the Continental U. S. reached $14.35 billion during 1953, a new record according to Secretary of the Interior McKay. It was 7 pct over the previous record of $13.43 billion set in 1952. While the greatest monetary gain was in fuels, there was a gain in nonmetallics and metals. This month's MINING ENGINEERING Annual Review issue presents a recapitulation of mining in 1953.

Arthur S. Fleming, Defense Mobilizer, announced a stepped-up program of procurement for national stockpile, and said Government is continuing to review full mobilization needs for aluminum and titanium production. The ODM chief issued a directive to the General Services Administration to go ahead in its procurement of all stockpile items not at their goal or contracted for already. He also said a titanium committee will be formed to study requirements and that this in all probability will result in revision upward of the current 25,000 ton goal.

ELEVEN CERTIFICATIONS OF DISCOVERY or development for domestic strategic minerals were issued during November, Defense Minerals Exploration Administration reported. It was the highest number for any month. Six certifications were for minerals on the national stockpile listing for intensified procurement. DMEA also announced that 63 new contracts for Government assistance in exploration for strategic minerals were signed in the four months ending with November. They included a record number of 31 contracts signed in October. The Government will provide up to $1,017,982 of an estimated total cost of $1,722,254 under the 63 pacts.

John L. Lewis called off the picket line which has been thrown around the Elk River Coal & Lumber Co. soft coal mine at Widen, W. Va. The strike had been in effect since September 1952. The dispute had nothing to do with wages, but was rather an attempt by the United Mine Workers to take over bargaining representation from the League of Widen Miners, an independent union. The mine is the second largest non-UMW operation in the nation. There were reportedly several instances of violence during the strike.

WESTERN MACHINERY CO., San Francisco, announced that its Western-Knapp Engineering Div. was awarded a contract to design, build, and equip a plant at Shiprock, N. Mex., to treat uranium-bearing ores. The contract involves some $3 million and will be executed for Navajo Uranium Div., Kerr-McGee Oil Industries Inc. of Oklahoma City, Okla. The plant will produce uranium oxide for the U. S. Atomic Energy Commission. It will be the first plant in the country designed expressly to treat uranium-bearing ores. Others have been adapted from plants previously treating other ores or placed in pre-existing installations. The new plant will be the first to use the so-called acidulation process of separating uranium oxide from carnotite ore. The process is said to insure maximum recovery and one on which Western-Knapp has done considerable experimental work. A large quantity of vanadium is also expected to result from operations. Plant completion is expected by December 1954.

Iron ore shipments by lake vessel from the Lake Superior region during 1953 season totaled 95,844,449 gross tons, railroad weights, for a new record. In 1952 74,910,798 tons were shipped from Upper Lake ports to Lower Lake points. The season in 1952 was interrupted by a 54-day steel strike.

Russians have increased offers of sale of manganese, chromium, and metals in the platinum group to the U. S., according to a spokesman for the Dept. of Commerce. The USSR put an end to sales of metals to the U. S. in 1948. Observers feel that the current move is based entirely on political motivations.

(Continued over)

Kennecott Copper Corp.'s Utah Div. made the largest single tax payment in the history of the State of Utah recently when it plunked down a check for $6,666,754.99 to County Treasurer Sharp M. Larsen. The check was for the company's 1953 property tax, based on valuation of net proceeds, real estate, improvements, machinery, and other personal property. Last June, Kennecott paid an occupation tax of $1,476,913.50, which under law goes to the state general fund. Property tax payment made recently was $1.2 million more than last year.

The U. S. Bureau of Mines has embarked on a program for development of portable or mobile devices which will be effective in reducing injuries and fatalities at the working faces of coal mines. One of the approaches that will be studied is the possibility of adapting to bituminous mines a movable arch-shaped steel shield of telescopic design already under consideration for anthracite mines.

CHEMICAL CONSTRUCTION CORP. signed an agreement effective February 15 to manage and operate Calera Mining Co.'s new cobalt refinery at Garfield, Utah. Chemico is a subsidiary of American Cyanamid Co., and Calera is a subsidiary of Howe Sound Co. Chemico will operate the plant for 2 years. Object of the contract is to give Chemico, designers and builders of the Garfield plant, an opportunity to put the operation on a commercial scale. Calera will supply cobalt concentrates from its mill at the Blackbird mine in Idaho. Chemico will process the concentrates on a toll basis.

Australian scientists are ashore in the Antarctic in an attempt to gain definite mineral information about the region. No one has ever lived ashore at the Australian sector of Antarctica, about 1500 miles south of Australia itself. It is already pretty certain that there is a coal seam running almost from the South Pole to the coast and within the eastern boundary of the Australian sector. The party expects to find definite outcroppings of copper, lead, silver, and possibly gold. No immediate handicap to mining is expected from the glacier conditions, often 6000 ft deep. Geological history of the area is reportedly similar to South American and South African regions. Immediate exploration efforts will be concentrated on the ample exposed areas.

WHITE PINE COPPER PROJECT in the Michigan Upper Peninsula is about two thirds completed and rapidly approaching final stages of construction. The $70 million project is expected to add 75 million lb of copper annually to U. S. production. Townsite is practically completed, with most of the houses finished and occupied. Hospital, school, dormitories, apartments, and service building are almost all finished. Ore is being stockpiled from underground development work. Partial production of copper concentrate is scheduled by August.

The Sun Never Sets
on SPRAGUE & HENWOOD'S
CONTRACT Diamond Core Drilling OPERATIONS
ANY KIND – ANY TIME – ANYWHERE
For more than sixty years Sprague & Henwood, Inc. has been a leader in the field of Contract Diamond Drilling. During this long period our crews have completed thousands of contracts successfully in every corner of the globe — under every conceivable condition.
From shallow holes to depths of more than a mile — in regions so remote that men and equipment were delivered by float planes — from barges on lakes and rivers — in mountain terrain so wild that mule-back transportation was required — from the blazing tropics to the sub-zero arctic — our crews have overcome every difficulty and completed their assignments to the customer's satisfaction.
Today, we have a large force of experienced operators and supervisors and an ample supply of modern equipment for every drilling requirement, so that we can undertake almost any job — anywhere — on very short notice.
Besides exploratory drilling for coal and ore, from the surface or underground, our contract service includes blast-hole drilling, directional drilling, foundation test drilling, grout holes and pressure grouting. Estimates, and constructive suggestions whenever possible, submitted promptly on request.
Manufacturers, also of high-speed diamond drilling machines, diamond bits and complete accessory equipment. Write for catalog.
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EIMCO

WORLD'S FINEST TRACTOR EXCAVATOR

TOUGHEST LOADING JOBS MADE EASY

The Eimco 105 — a bigger, heavier, faster machine — makes the toughest loading jobs easy.

Excavating in many materials that have to be drilled and blasted for ordinary loading equipment is customary with the 105. Loading rough, blocky-rock is easy with the 105. As an example, one assignment was the removal of debris and molten slag from an open hearth slag pocket in a steel mill. Not only did this material consist of molten masses but the bottoms were consolidated into heavy layers of brick, slag, and steel. The 105 efficiently removes all of this material, digging up the bottom layers and breaking it into 6 or 8 ton chunks for loading into a railroad gondola.

Write for complete information on the Eimco 105 to The Eimco Corp., Salt Lake City 10, Utah

THE EIMCO CORPORATION

Salt Lake City, Utah, U.S.A.

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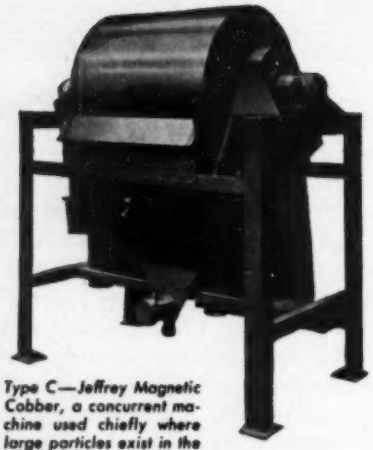

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AERO* PROMOTER 404

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A powerful, water-soluble flotation promoter AERO* Promoter 404 is finding increasing use as a supplementary promoter and as a replacement for conventional promoters. Its use at many flotation operations has sharpened selectivity, increased recovery and reduced reagent costs. Current applications include flotation of auriferous pyrite and pyrrhotite, tarnished and oxide lead, lead-zinc, copper-zinc, copper-lead, free gold, copper-cobalt, cobalt and other complex precious and base-metal ores.

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SOLUTION: Use AERO* Promoter 404 in conjunction with former promoter.

RESULTS: Copper and cobalt grade improved; cobalt recovery increased; frother consumption cut from 0.06 to 0.03 lb. per ton.

Lb./Ton Reagents		% COBALT		% COPPER	
		Grade	Distribution	Grade	Distribution
0.45 Prom. A 0.06 Frother	Feed	0.65	100	0.90	100
	Cleaner Conc.	8.70	81.3	14.14	96.2
	Cleaner Tails	0.64	5.6	0.29	1.8
	Rougher Tails	0.097	13.1	0.02	2.0
0.15 404 0.30 Prom. A 0.03 Frother	Feed	0.65	100	0.86	100
	Cleaner Conc.	10.40	83.2	15.91	96.2
	Cleaner Tails	0.91	5.3	0.39	1.7
	Rougher Tails	0.082	11.5	0.02	2.1

Cyanamid Field Engineers will be glad to discuss AERO* Promoter 404 usage with you, can supply samples for mill-lab tests, and will assist you with mill testing. Their primary job is to give you unbiased counsel and practical help in working out the best reagent combination for your ore. Your inquiry to our nearest Mineral Dressing office is invited.

*AERO is a trade-mark of American Cyanamid Company applied to flotation reagents and chemicals used in ore beneficiation plants or processes.

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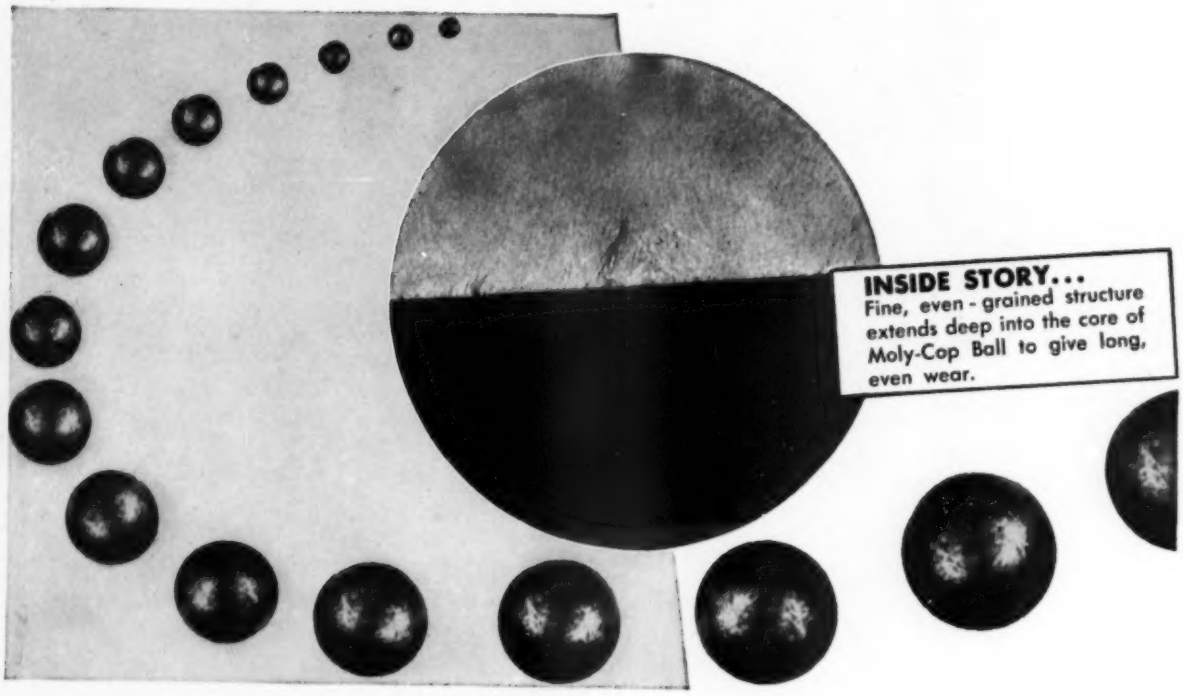

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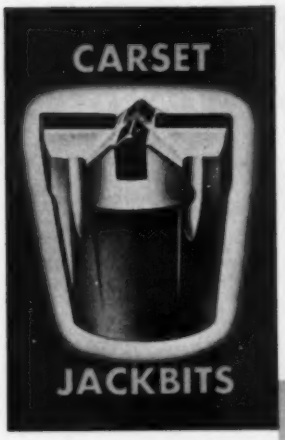

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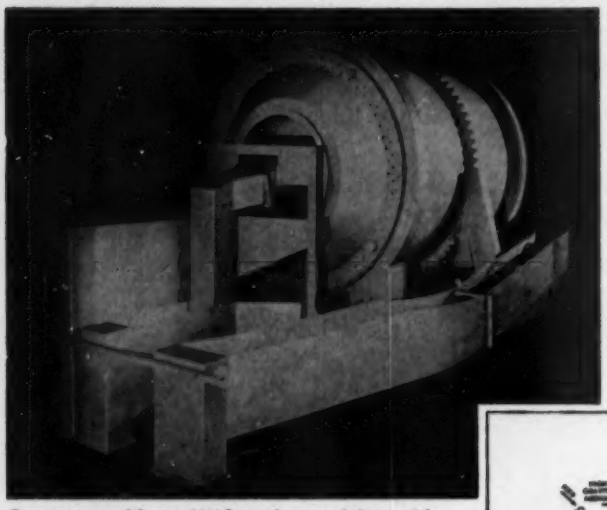

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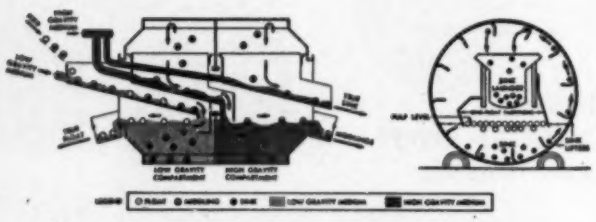

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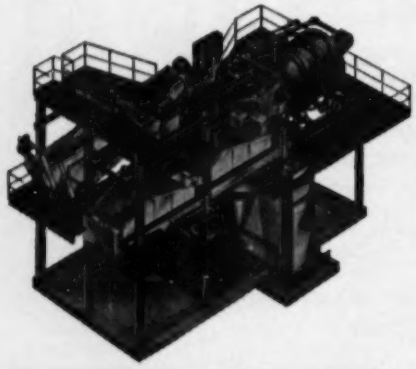

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Tungsten Mining Corp. Expands Mill

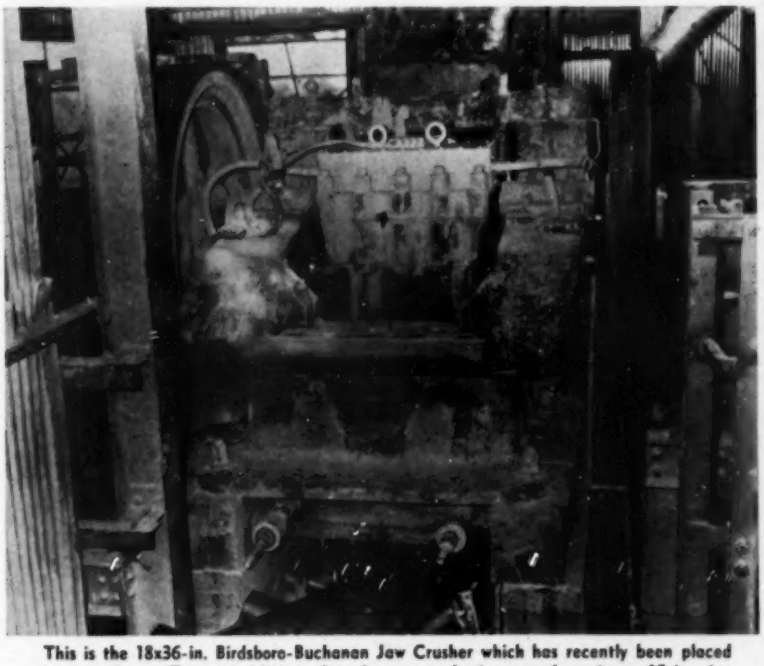
Tungsten Mining Corp. of Henderson, N. C., the country's top tungsten mine, is primary crushing 650 tons of ore daily with an 18x36-in. Birdsboro-Buchanan jaw crusher. This machine has been instrumental in the firm's recent production increase from 300 to 650 tpd. Ore is highly abrasive white quartz containing speckles and patterns of black hubnerite, the tungsten mineral.

Ore passes over a 12-in. grizzly bar atop the ore bin, then feeds to a 36-in. inclined belt. The belt operating at 100 fpm, serves as picking belt for removing wood and foreign matter. This belt also feeds the crusher, which operates at 222 rpm with a 1¾ to 2-in. setting. Secondary crushing reduces ore to ½ in. Crushing section produces 45 to 50 tph, operating two shifts daily, 7 days a week.

Marcy peripheral-discharge rod mills replaced crushing rolls for reduction to ⅛ in., and also for regrind to 0.07 in. Substitution for crushing rolls was made although rolls performed well metallurgically. They were inclined toward mechanical difficulties and produced excessive dust. Treatment starts with −⅛ in. material, using jigs, followed by tables, and finally batch flotation for sulphide removal. New slime treatment section, which has raised overall recovery, uses three 20-in. Centriclones to make a split at 15 microns.

This is the mill of Tungsten Mining Corp., at Henderson, N. C., where the number one producer of tungsten in the U. S. has been expanding facilities.

Primary slime recovery is made in a battery of ten Denver-Buchman tilting concentrators, arranged in two parallel banks of four roughers and one cleaner each. A product suitable for the flotation circuit is obtained by upgrading on conventional Deister Concentrator Co. tables. Concentrate is pumped to a storage tank from which it is removed to batch bulk flotation for sulphide removal. Filtering and drying prepare concentrate for magnetic separation of final product.



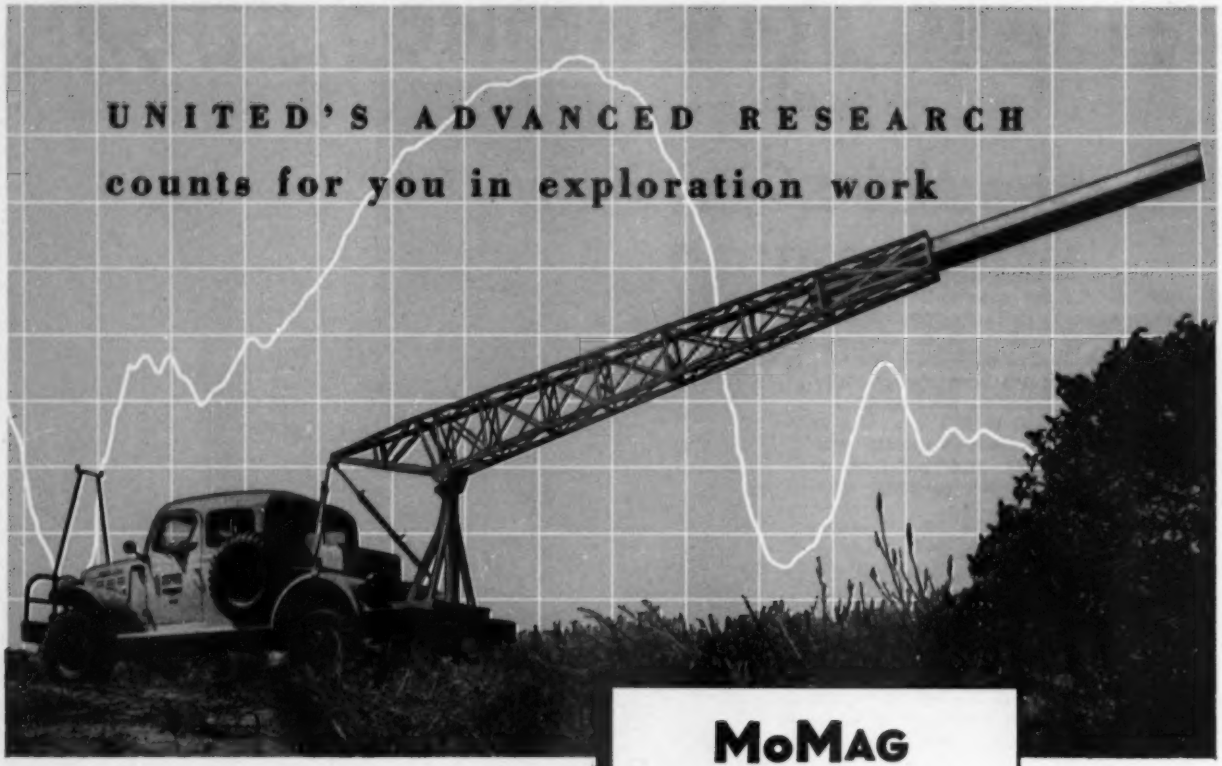
This is the 18x36-in. Birdsboro-Buchanan Jaw Crusher which has recently been placed in operation at Tungsten Mining. It reduces run-of-mine ore of maximum 12-in. size to 2 in. at the crusher discharge. The crusher handles 650 tons of ore daily.

Infrared Dryers

Tungsten Mining Corp. claims world's first infrared concentrate dryers. Operating cost of the dryers is about $2.00 per ton. They require little maintenance and produce almost no dust. Most important, there is no magnetization of iron sulphides, something that would interfere with final magnetic separation.

One drier handles jig concentrate, the other table-flotation product. Each drier has 0.3 tph capacity and is equipped with 70 GE 375-w infrared bulbs. Power consumption for both driers is 52.5 kw, or 87.5 kw per ton.

Tungsten Mining Corp. expects to mill between 250,000 and 275,000 tons of ore during 1954.



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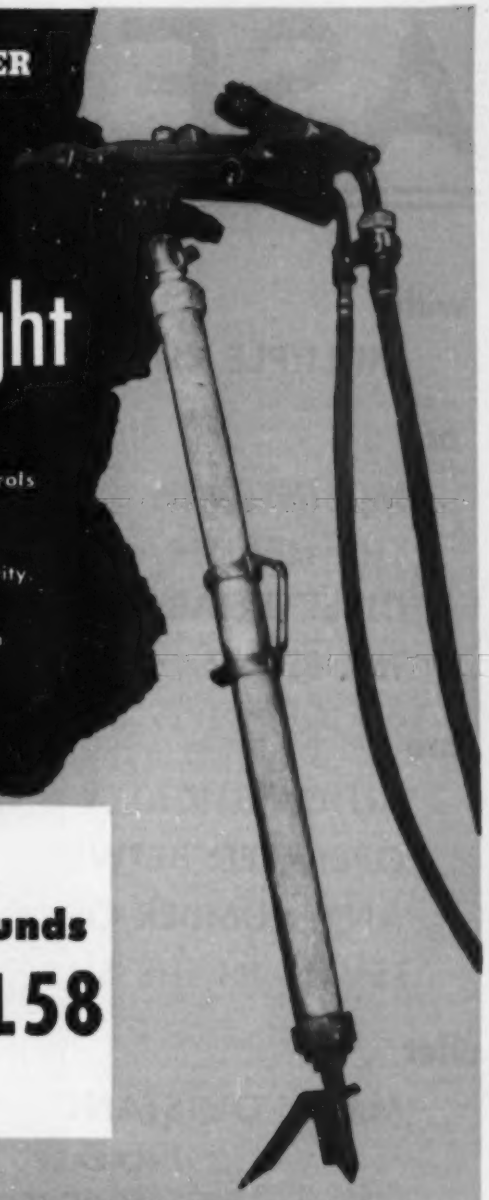

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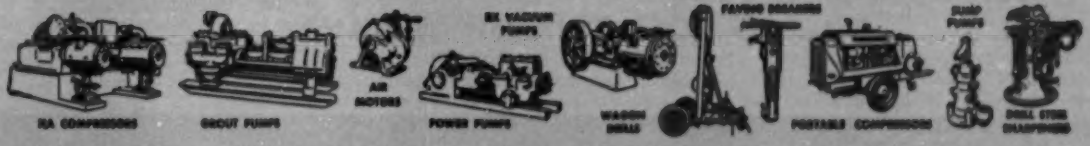

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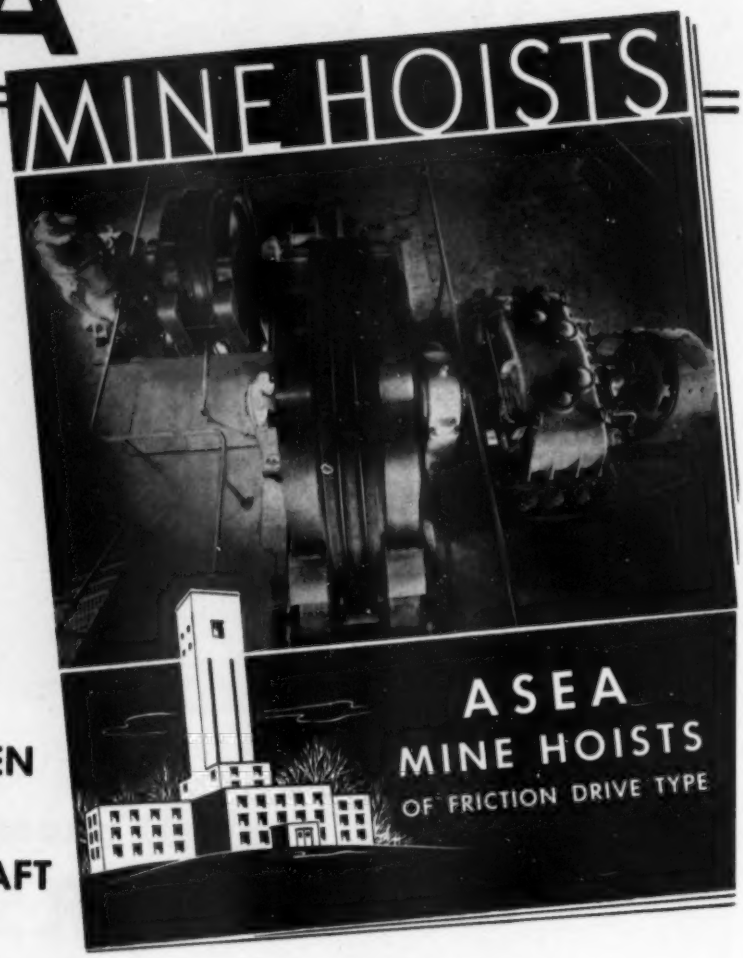

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Three Mine-Mill Locals Bolt Back to CIO Fold

by Myron A. Matzkin
News Editor

Three big local unions of the Independent Mine, Mill & Smelter Workers left the fold and moved over to the CIO's United Steelworkers union. It was another chapter in the history of disagreement between the CIO and Mine-Mill dating back to 1950. That year the CIO cut the Mine-Mill loose, charging that the nonferrous union was Communist dominated and following the party line.

This is what happened last December when Butte Miners Union No. 1, Anaconda Mine-Mill Local No. 117, and the Butte Stationary Engineers Union made their bolt back to the CIO.

Anaconda Mine-Mill, with 2000 members, issued a statement similar to the one issued by the Butte Miners Union. The Butte union has a membership of about 5000.

The Anaconda Resolution said:

1. This local union withdraws and disaffiliates . . . from the International Union of Mine, Mill, and Smelterworkers.
2. The officers of this local union are directed to apply to the United Steelworkers of America, CIO, for a local union charter, and to take whatever steps may be necessary to bring about the affiliation of this local union with the United Steelworkers of America, CIO.
3. The officers of this local union are directed to continue to administer the collective bargaining agreements to which this local union is a party.
4. The officers of this local union are authorized and directed to take whatever steps may be necessary to protect the funds and other assets of this local union, to the end that they may be secured and preserved for this local."

In other parts of the resolution the local records that it has long been disturbed by evidence of Communist domination of the officers IUMM&SW. ". . . for three years now, since expulsion of Mine-Mill from the CIO, we have sought to preserve the effective and democratic operation of this Local Union, and to recapture the International Union from the clutches of the Communist stooges into which it has fallen. Our hopes have not been realized. The time has come for this Local Union to break the bonds through which the International Union officers subordinate our interests to Soviet Russia."

President Walter Dooley, of the Anaconda local, in commenting on the action of his union said: "Action of the union was taken only after careful study and deliberation. The smeltermen of Anaconda, and the same is true of the rank-and-file membership of other locals in IUMM&SW, want a democratic union, controlled only by the members, and loyal to the principles of democracy . . . They want no part of a union dwindling in membership because of the 'party line' activities of some of its officers."

CIO Chief Walter P. Reuther says that Mine-Mill is disintegrating and that half the membership claimed by Mine-Mill in 1950 has left the union and for the most part moved over to the CIO.

In Denver, officers of the Mine-Mill International called the move back to the CIO a maneuver by a handful of opportunists "who have failed to give true union leadership in the fight for higher wages and the welfare of their membership." The International office claimed that only 200 of the 5500 membership of the Butte local attended the secession meeting. Of those who did attend, International Union leaders said, only a small group actually took part in the vote. The Mine-Mill International office stated that a move from the floor to submit the action to a referendum was ignored.

It was pointed out by the Denver group that Anaconda Mining Co. workers at Great Falls rejected the Steelworkers Union in an NLRB election about 19 months ago.

CIO Gives Its Side

In the meantime, Walter P. Reuther, CIO president, in a year-end statement, said that Mine-Mill is disintegrating. He also pointed out that when the CIO threw the nonferrous union out its findings carried no implication that the individual members of the union are Communists or favorable to Communism.

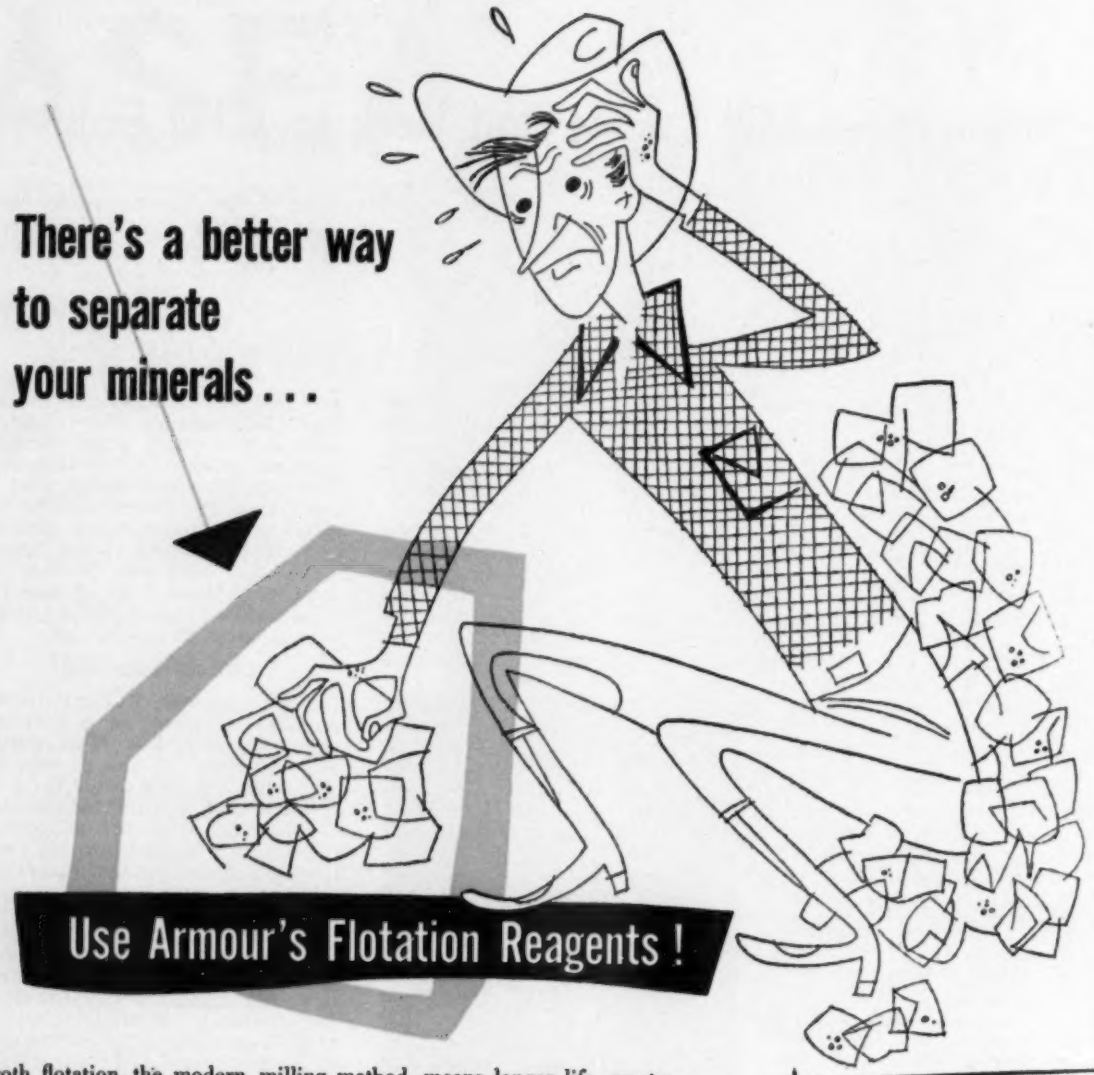
"In the four-year period since expulsion of Mine-Mill from the CIO, the Communist-dominated leadership of the International Union of Mine-Mill has proven a hundred times their 100 pct devotion to Communist ideas . . . Communist leaders of the International Union have used all sorts of devices and maneuvers to keep themselves in power, concealing all the while the fact that the Union's policies and activities were not the real informed decision of the members but determined in accordance with the line of the Communist Party."

Reuther claims that about half the membership Mine-Mill boasted in 1950 has left the Union, mostly to join the CIO. As a result, it was stated by Reuther, more nonferrous metal workers are in the CIO than in the Mine-Mill. Reuther feels that the trend toward the CIO and away from Mine-Mill is on the upgrade.

Reuther, in making an appeal to all members of the Mine-Mill to come back to the CIO, promised all possible help, moral and financial.

The CIO analysis of the situation is summed up this way: "The Mine, Mill, and Smelterworkers Union is disintegrating. It can no longer offer leadership and protection to nonferrous workers. These workers are anxious to return to the mainstream of American trade unions—the family of CIO unions."

There's a better way to separate your minerals . . .



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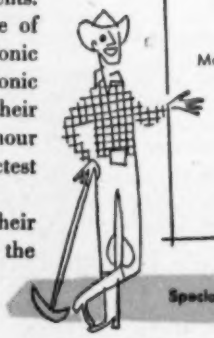
Feldspar • Fluorspar
Hematite • Ilmenite
Kaolinite • Magnetite
Manganese • Manganite • Mica
Phosphate • Potash • Salt
Silica • Spodumene
Syenite • Talc • Tin
Vermiculite



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From Leadville to Fairplay—By Pack Burro and Fortitude

Probably the most unique race in the world is run at Fairplay, Colo. As far as anyone has been able to determine, it is the only authentic pack burro race known to man—or beast. Contestants *sprint* some 23 miles between Fairplay and Leadville, Colo.

The course winds its way through the Rocky Mountains, over Mosquito Pass with a 13,180-ft elevation at its highest point. The route traverses what used to be a stagecoach run. About 13,000 people attended the last race, won by Joe Taylor of Buena Vista, Colo., with Don Anderson of Leadville, second, Bob Cooper, Fairplay, third, and Harold Peterson, Denver, fourth. Two women, Edna Miller, Alma, Colo., and Beverly Weeks, Fairplay, were among the 24 entries. Both ladies finished the course, with Edna Miller finishing 28 minutes behind the winner. Winning time was 4 hr, 51 min, and 44.8 sec.

Contestants in the race between Fairplay and Leadville line up at the starting point. Some of the burros had to be persuaded that this was the way to do things. A certain recalcitrance was noted on the part of several of the entries.

Mosquito Pass, with an elevation of 13,180 ft at its highest point, is one of the most grueling tests of the entire 23 mile race. Some of the burros had to be pushed, pulled, or coaxed over the pass.

The winner received $700, while second, third, and fourth place were worth $500, $200, and $100 respectively. Anyone crossing the finish line within an hour of the winner received his or her $25 entry fee back.

Each Burro carries a 50-lb pack, consisting of gold pan, pick, shovel and other old-time prospecting equipment. The tender has a 15-ft lead rope controlling the animal, but no prodding device is permitted. The team may walk, crawl, run, but riding is not allowed. The burro may *even* be "carried" over the pass. Officials cover the route to "keep things on the square."

Two of the contestants in the pack burro race relax at the finish line and watch the other contestants "pound" down the home stretch.

Some of the contestants wore beards and carried the silks of a variety of burro lovers. The race wound up Evans Gulch east of Leadville at Evansville and then headed for Mosquito Pass. Some of the burros set a pretty fast clip, while others showed little early foot and needed considerable encouragement. Evansville was once an active mining community, but like the burro, its place in the mining industry has diminished.

U. S. Mineral Production Sets Record Dollar Value

The U. S. Bureau of Mines estimates indicate that U. S. mineral industries reached tremendous levels of actual production and dollar value. Metallics, nonmetallics, and fuels showed decided gains, with the iron ore field exhibiting one of the most spectacular comebacks in its history.

U. S. Mineral Production 1950-1953

	(Billions of dollars) 1950	1951	1952 (preliminary)	1953 (estimate)
Nonmetallic minerals:				
Fuels	8.7	9.8	9.6	10.2
Other	1.8	2.0	2.2	2.4
Total nonmetallic	10.5	11.8	11.8	12.6
Metals	1.4	1.7	1.6	1.8
Grand total	11.9	13.5	13.4	14.4

U. S. Mineral Production — 1953

Commodity	Unit	Estimated Production 1952	1953	1953 Value Thousands of Dollars
Fuels:				
Anthracite	ton	39,475,000	30,000,000	$ 278,000
Bituminous Coal & Lignite	ton	466,841,000	450,000,000	2,241,000
Natural Gas*	million cu ft	8,100,000	8,425,000	716,000
Petroleum (crude)	thous bbl	2,289,836	2,359,000	6,369,000
Nonmetallics:				
Asbestos**	ton		55,000	5,000
Cement	bbl		262,000,000	700,000
Feldspar	LT	420,831	420,000	4,000
Fluorspar	ton	346,315	325,000	15,000
Graphite	ton	5,606	5,000	600
Gypsum	ton	8,415,000	8,700,000	24,500
Mica (scrap)	ton	75,236	78,000	1,970
(sheet)	lb	908,135	828,000	1,070
Phosphate Rock	LT	12,031,213	13,100,000	78,500
Potash (K_2O)	ton	1,732,935	1,800,000	60,534
Pyrites	LT		1,000,000	5,000
Salt	ton		20,000,000	71,000
Sand & Gravel	cu yd		475,000,000	450,000
Slate	ton		800,000	13,500
Stone	ton		300,000	475,000
Sulphur	LT		5,200,000	112,000
Vermiculite	ton		210,000	2,100
Metals:				
Aluminum (ore)	LT	1,667,047	1,600,000	10,000
Antimony	ton	2,160	200	N.A.
Beryllium	ton		750	335
Cobalt	lb	2,193,597	1,740,000	N.A.
Chromium	ton	21,304	58,000	3,600
Copper	ton	925,377	926,000	530,000
Gold	troy oz	1,648,128	1,685,758	59,002
Iron Ore	LT	97,236,397	117,000	795,000
Lead	ton	390,168	340,000	90,400
Manganese	ton	116,300	160,000	12,000
Mercury	76 lb flask	12,547	14,300	2,775
Molybdenum	lb	43,259,000	58,800,000	57,000
Silver	troy oz	39,116,616	38,630,957	34,963
Tin	LT		20	45
Titanium (Ilmenite)	ton		472,000	760,000
Tungsten (60 pct WO_3)	ton	7,600	9,200	34,500
Zinc		666,001	540,000	118,000

* Marketed production.
** Canada produces 65 pct of world supply.

Mineral industry production in the U.S. during 1953 reached an all-time high in dollar value, surpassing by 7 pct the record set in 1952. Estimated worth of U. S. production is $14.3 billion, with the greatest gains occurring in fuel minerals. However, metallics and nonmetallics also climbed.

Coal continued to show a decrease in output, but decline in that area was offset by new peaks in petroleum and natural gas output—both in volume and dollar value.

Record Iron Ore Production

Iron ore production, against the background of the disastrous steel strike of 1952, totaled 117 million long tons, topping the last record year, 1951, and beating 1952 output by 20 pct. Total 1952 production was 97.2 million tons. New and larger Great Lakes ore carriers were significant in the year's tremendous iron ore output.

Ferroalloy metals production in the U. S. increased substantially, with the exception of cobalt concentrates. While cobalt production declined 10 pct from 1952, consumption of the metal will prove to be about the 1952 high of 10.8 million lb, according to estimates. Chromite continued to be produced and consumed at a record rate during 1953, with domestic output triple of that of 1952. Stimulated by General Services Administration's purchase program, manganese production went up to 160,000 short tons.

Molybdenum production last year failed to come up to the record 1943 mark by only a small margin—while actually passing the record for the second half of the year. Preliminary data indicate that the U. S. accounted for 90 pct of world molybdenum production.

Copper Production Steady

Copper price decontrol in 1953 made more of the metal available to the U. S. market than in any recent year. Nevertheless, domestic production, 926,000 tons, remained at the 1952 level. Abnormal asking

price for Chilean copper throughout the year caused a substantial decrease in imports of the metal from that country. Overall price for copper in 1953 was 28.6 cents per lb, compared with a controlled price of 24.2 cents in 1952. Increased demand was met by more than adequate supplies and a generally anticipated price decline did not materialize.

Lead-Zinc Supply Adequate

Slab zinc production in the U. S. totaled 1.0 million tons, another record, but contrasted with that was an all-time low in mine output—only 540,000 tons—lowest since 1938. Many mines were closed or operating on sharply curtailed schedules in the face of a new import record—525,000 tons.

Lead found itself in a situation similar to that of zinc. While supplies were plentiful and imports rose from 542,000 tons in 1952 to 545,000 tons in 1953—mine production fell to 340,000 tons—a decline of 50,000 tons from the previous year.

With the exception of silver, output of rare and precious metals increased.

Nonmetallics Climb

Another record was tacked up in the nonmetallic mineral raw material field, with decreases in some more than offset by new highs established by others. Production of fertilizer minerals was higher in 1953 than in any previous year, but a decrease in consumption was exhibited in the second half. While asbestos production in Canada improved considerably, strategic grades remained tight.

Domestic production of rutile, the mineral on which titanium metal production is now based, was slightly greater in 1953 than in 1952. The U. S. continued to import to fill its needs, and about two-thirds of the nation's supply came from Australia, sole foreign supplier since 1947. U. S. production of the titanium mineral ilmenite was about 9 pct lower in 1953 than in 1952. India continued to be the prime supplier, with about 20 pct of total requirements imported. Titanium slag imports were about triple those of 1952.

Current, plus anticipated scarcity of titanium metal for defense led Defense Materials Procurement Agency to contract with the Bureau of Mines for production of 180 short tons of titanium over an 18-month period. The metal will be produced at the Bureau's Boulder City, Nev., pilot plant.

Domestic production of bauxite remained unchanged over that of 1952 at 1.6 million tons. Imports increased 1 million long tons to about 4½ million tons from 1952 to 1953, as a result of new mining operations of Reynolds Jamaica mines and Kaiser Bauxite Co. in Jamaica. About 95 pct of U. S. came from Arkansas.

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BRANCH OFFICES AND WAREHOUSES THROUGHOUT NORTH AMERICA

THE Special Subcommittee on Minerals, Materials and Fuels Economics of the Committee on Interior and Insular Affairs has just issued the first part of its report after hearings in Washington, D. C., Seattle, and Henderson, Nev. Other hearings are scheduled for Los Angeles, Salt Lake City, and again in Washington. It has heard testimony from engineers, producers, and Government officials. While some of the hearings were held in executive session because of security requirements, the committee states in its initial report that testimony revealed a "shocking" shortage of certain strategic materials. This shortage of strategic critical materials is to be investigated in separate hearings.

The report states that: "We have become dependent upon foreign nations across one or both major oceans for many of the materials without which we cannot fight a war or support our economic structure."

It is also stated that the stockpile program, scheduled for completion by 1951, was extended to 1953. It is now doubtful that the program can be completed by 1958, the report said. Contracts for strategic materials, it was disclosed in secret sessions, show that terms were more favorable to foreign producers than to "domestic American producers." The report of the subcommittee finds that the terms of these contracts are contrary to stockpile law and national security. During hearings, several military strategists stated disbelief in the possibility of keeping long sea lanes open during time of war.

The committee recorded complaints that have reached them relative to domestic production to be: trade agreements made by the State Dept. under the 1934 Trade Agreements Act; taxes, direct and indirect; regulations governing venture capital by the Securities and Exchange Commission; favoritism toward purchase of foreign materials over domestic sources under the Stockpile Act; and currency manipulation and participation for trade advantage by foreign governments both in the U. S. and abroad.

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FALCONBRIDGE Nickel is expanding facilities at its Norway plant to provide 45 million lb of nickel per year, but its eventual goal for overall operations is 60 million lb by 1960. One report has it that the additional plant to furnish the 15 million lb may be located in the Sudbury district of Canada. The company has a new pyrrhotite treatment process which is said to show promise of fitting into future plans. The *Northern Miner* reports that foundations for the plant are being poured and deliveries of structural steel are scheduled to start. Plans are to divert 200 tons per day of pyrrhotite from the Sudbury smelter to the new plant.

The plant is being built on the slag dump of the smelter. While recovery of nickel is the prime factor, there are indications that a salable iron ore will be produced as a byproduct. According to the *Northern Miner* some completely new principles are being used in the new process which also lends itself to treatment of other complex base metal ores. Tests are reported to indicate that metal recoveries are greater than those from selective flotation on some difficult ores and with moderate cost. It is concluded that plant investment would be no greater than for an electrolytic refinery of equal capacity. While neither Falconbridge nor International Nickel, who also has a pyrrhotite method, have disclosed process details, it is believed there are significant differences.

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FREE world nickel production, when estimates are finalized, is expected to reach about 340 million lb for 1953, an increase of about 20 million lb over 1952, John F. Thompson, chairman of the board of directors of International Nickel Co., stated. Canadian output of the metal will reach 285 million lb for 1953— or about 85 pct of free world output. The U. S. took more than 65 pct of the total production for both defense and civilian needs. The steel industries of the U. S., United Kingdom, and Canada were the greatest users of nickel in the production of stainless steels, engineering alloy steels, and jet engine alloys.

Nickel production in 1954 should reach about 385 million lb. Based on announced expansion programs, free world nickel capacity by 1960 should be at least 75 pct greater than that existing in 1949. Annual production in 1949 was about 265 million lb. Much of the 1954 increase is already under contract to the U. S. for defense and stockpile purposes.

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THE Territorial Dept. of Mines, Alaska, publishes a rather unique periodical called the TDM Bulletin. Its coverage includes as much of interest to Alaskan mining men as can be crammed into its mimeographed pages. A typical issue contains a listing of items of interest in the four divisions, ranging from court action on a claim jumping charge to mine development, prospecting, and mineralization discoveries.

One section contained an article on tungsten-carbide tipped hand steel for prospectors who wish to develop properties where a drill cannot be taken. Another item offered field tests for the presence of nickel—a metal much sought after in Alaska today.

Other items are those that are usually classified as personals, but form an important fund of information for the Territorial miner. The Territorial Dept. of Mines, incidentally, is undertaking the compilation of a mineral deposit inventory. The U. S. Geological Survey is making much information available to the department, having worked on a somewhat similar project for a number of years.

BITUMINOUS coal mines produced about the same tonnage in 1953 as in the previous year, but mine operators poured some $500 million into the industry for new equipment, maintenance, and repairs. Mine output is expected to total about 450 million tons for 1953, compared with 467 million in 1952. However, U. S. consumption for 1953 is expected to amount to 426 million tons, an improvement over 1952 consumption of 419 million tons.

Production for the first quarter of 1954 is predicted at 110 million tons, slightly higher than for the first three months of 1953. Railroads consumed less coal in 1953 than the year before, 28 million tons against 38 million. However, other industrial users consumed 97 million tons—a 1 million ton increase. Retail distribution of coal, according to latest U. S. Bureau of Mines statistics, will probably reach 60 million tons, compared with 68 million for 1952.

Overseas shipments of coal fell off to 14.5 million net tons, while Canada bought 20 million tons, 1 million less than in 1952. The Bituminous Coal Institute expects that the steel industry will use more than 100 million tons of coal in 1954. Electric utilities used more coal in 1953 than ever before—112 million tons, and the Institute expects the industry to establish another record in 1954.

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EVEN work well done can end in financial disaster because there is "no protection from richer deposits, lower cost operations, or substitute materials," according to Arthur H. Bunker, president of Climax Molybdenum Co. The statement refers to his early experiences producing radium on the Colorado Plateau. At that time it was an entirely unique mining venture—posing entirely new problems. Radium during the period immediately following World War I was a new and somewhat dangerous medical tool. The men who produced the radium had to teach doctors how to use the stuff. Training courses, a radiology periodical, and medical applicators had to be created. Radium sold for the fantastic price of $3.5 million per ounce, and an ounce represented a whole year's production. It took between 3 and 5 million parts of ore to find the one part of radium.

After several million dollars had been invested on the plateau, Bunker said, the Shinkolobwe mines in the Belgian Congo were discovered with ores forty times as rich as the best in Colorado. It killed the Plateau radium industry.

Bunker lost his job and started looking for something else to do. Vanadium had been discovered on the western slope, but the established producers turned it down as uneconomic. Bunker and several others tried a new processing idea in the laboratory. "It worked."

The idea was a radical one and only half the capital needed could be raised. They went ahead anyway. The first batch of vanadium "disappeared into the bricks of the furnace. The second batch slipped by the filter presses down the drain into the Colorado River—about $20,000 worth of it." Despite lack of capital and various failures, the business survived and is still a very healthy enterprise at Rifle, Colo.

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SOUTH African mining circles were considerably shaken recently, according to a *New York Times* correspondent, when white workers at the American-controlled Roan Antelope mine in Northern Rhodesia voted for removal of the color bar. The mine's white workers represent about one fourth of the whites in the Northern Rhodesian industry.

The Roan Antelope white workers voted to remove the clause of their agreement with copper producers limiting employment in the higher paid and more skillful jobs to white men.

Gert Lombaard, in the new goldfields of Odendaalsrus, Orange Free State, speaking for the white South African Gold Miners Union, called on white miners to resist this move. He stated that there was no room in mining for whites and negroes.

Lombaard scored a request from Sir Ernest Oppenheimer, Anglo-American Corp. head, to Northern Rhodesian white miners to give nonwhites a chance at more highly skilled jobs. Anglo-American is termed by the *New York Times* to be the greatest mining trust in southern Africa. Reportedly, the issue has been expanded considerably by the anti-color bar policy of the Rhodesian Selection Trust, controlled by a New York firm.

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A characteristic of the material handling industry in 1953 was the merging of equipment manufacturers. "A manufacturer of electric trucks for inside work expanded his line to include gasoline powered vehicles and acquired another company to offer equipment for outside handling," is one example presented by Howard M. Palmer, president of the Material Handling Institute Inc. Others followed suit. The industry's volume reached 1¼ billion dollars worth of material handling equipment. The equipment produced made it possible to reduce cost and bring about more efficient production of $108 billion worth of manufactured goods, plus warehousing and distribution of these goods. Contributing to the growth of material handling equipment production was the increased leasing and renting of equipment and more long-term financing for purchases.

Use of electronics in control of material handling equipment points the way toward more complete automation. But the materials handling producers face the same problems that other areas of the capital goods industry are meeting. "Manufacturers will need more trained engineers than are now available to design, build, and sell the tools of material handling. The need is . . . for men who can translate successful material handling techniques from one industry to a different one."

Overall view of the plant with a 120' dia. Dorr Thickener in the left foreground handling flotation tailings. A 40' dia. Dorr effluent Thickener and 40' dia. Dorr Hydroseparator are at the right. All three units are covered to prevent temperature increases resulting from the sun's rays.

NEW MEXICO POTASH PRODUCER

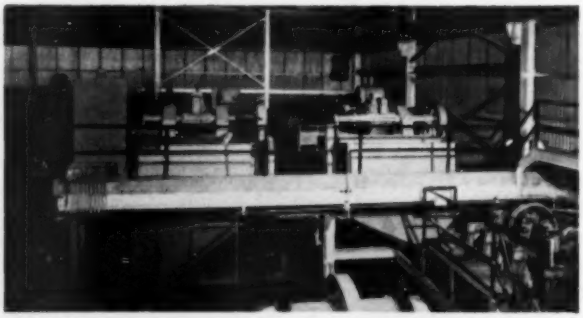
Combines Chemical and Metallurgical Techniques at New Plant . . .

A new U. S. producer for the quality potash market, Duval Sulphur & Potash Company recently started up this modern plant near Carlsbad, New Mexico. A perfect example of the growing convergence of chemical and metallurgical techniques, the plant makes skillful use of the latest developments in both fields.

The flowsheet includes crushing, grinding, classification, hydroseparation, flotation, thickening, centrifuging, crystallization and drying.

At Duval, as throughout the chemical and metallurgical industries, Dorr equipment and techniques play a vital part in wet processing flowsheets. For more information on the scope of the Dorr technical service, write for bulletin No. 7002. The Dorr Company, Stamford, Conn. *In Canada:* 26 St. Clair Avenue, E., Toronto 5.

Closeup of two Duplex Dorr HX Classifiers. The Primary at right handles raw crushed salt which has been pulped with return brine. Sands go to a rod mill and fines to the Hydroseparator.



General view of the milling section. Rod mill discharge goes to the Secondary Classifier at the right. Sands are discharged to conditioners and fines overflow to the Hydroseparator.

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Drift of Things

NO doubt to the casual observer the life of an Institute President is "just a bowl of cherries," but we have accumulated a few facts on the duties that indicate that this is not necessarily so. Beginning with September 10 and following through the month of October, we find that President Andrew Fletcher had a pretty rough schedule:

Sept. 10. Arrived at Sydney, Nova Scotia, and traveled by automobile to Keltic Lodge at Ingonish Beach for the Industrial Minerals Div. Fall Meeting. Spoke at the dinner.

Sept. 11. Attended meeting activities.

Sept. 12. Traveled from Ingonish Beach to Antigonish, Nova Scotia, received an honorary degree of Doctor of Laws and delivered the Convocation address.

Sept. 13. Left Halifax, Nova Scotia to return to New York.

Sept. 18. Attended a meeting of the Oregon Section at Portland. Eighty men and wives attended and President Fletcher spoke to the group.

Sept. 19. Met with Seattle AIME Members with an attendance of 50 people.

Sept. 21-24. Attended American Mining Congress meeting at Seattle and presided over an AIME Board meeting.

Sept. 25. Attended a meeting of AIME Members at the Consolidated Mining & Smelting Co. plant at Trail, B. C.

Sept. 26. Attended a joint meeting of the Canadian Institute of Mining and Metallurgy and members of the Spokane Subsection at Trail, B. C.

Sept. 27. Visited Metalline Falls, Idaho, and toured Pend O'Reille Lead & Zinc Co.

Sept. 28. Addressed the Northwest Mining Assn. at Spokane at a luncheon meeting. Attended an evening meeting of the Spokane Subsection with an attendance of 125.

Sept. 29. Visited major operations in the Coeur d'Alene district and met with AIME Members in Kellogg, Idaho.

Oct. 1. Stopped at the Anaconda smelter at Anaconda, Mont., where a special AIME luncheon was held for the President. A dinner meeting of the Montana Section was held in Butte at the Finlen Hotel.

Oct. 13. Visited Phelps Dodge operations at Morenci, Ariz., and attended an evening meeting with the Morenci Subsection.

Oct. 14. Inspiration and Miami companies held a special dinner honoring the President at Globe, Ariz. Seventy-six AIME members attended from Ray, Inspiration, Miami, Superior, and Globe.

Oct. 15. Special meeting of the Ajo Subsection—62 attended.

Oct. 16. Phelps Dodge Corp. held a luncheon for the President in Ajo.

Oct. 20. Toured in Tucson and visited the new operations at San Manuel.

Oct. 21. Met with students of the University of Arizona at a gathering sponsored by Arizona Section Woman's Auxiliary, where Mr. and Mrs. Andrew Fletcher were guests of honor.

Oct. 22. Visited Phelps Dodge smelter at Douglas, Ariz.

Oct. 23. Dinner dance at Bisbee, Ariz., under the auspices of the Bisbee and Douglas Subsections.

Oct. 24. Attended a luncheon at Silver City, N. Mex., given by Kennecott Copper Co. and attended an evening meeting with the Southwestern New Mexico Section at Silver City.

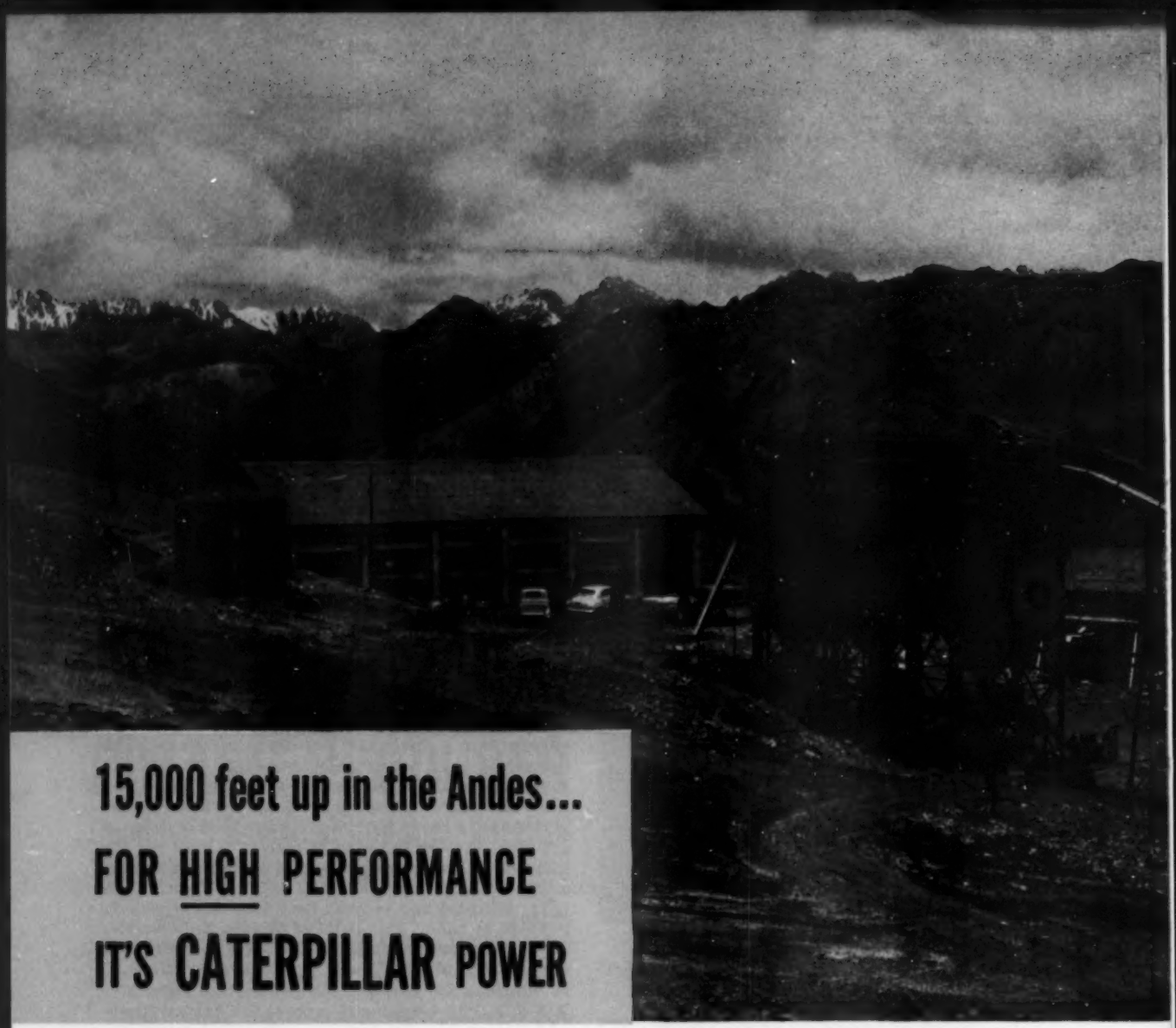
Oct. 26. Visited International Minerals & Chemical Co. and U. S. Potash plants at Carlsbad, N. Mex., and attended a special meeting and dinner given by the Carlsbad Section.

Oct. 27. Arrived at El Paso and attended the Fall Meeting of the Mining, Geology, and Geophysics Div. and International Mining Days.

We probably shouldn't print this—it's apt to scare off the upcoming Presidents, and future ones to be chosen—but it does give a little better idea of the work load that comes with the AIME Presidency. Rewards are the kind that go with doing a terrific job well—knowing that in the year of office one has performed a duty for which the membership is grateful. It takes the kind of men who have led the Institute in the past and who are already set to lead it in the future. Leo Reinartz will be President in 1954. His past and present lend themselves well to the task at hand. This issue of MINING ENGINEERING contains a brief sketch of Mr. Reinartz as the editors see him.—C. M. C.

MEMBERS planning to come to the Annual Meeting in New York by air will find that the airlines bus terminal at Park Ave. and 42d St. has been replaced by a new terminal at 1st Ave. and 37th to 38th Sts., about 15 minutes' walk from the former location. To get from LaGuardia or Idlewild airports to midtown Manhattan requires a bus ride to the terminal and a taxi ride from there to one's hotel. Passengers deplaning at Newark airport are more fortunate in that the airport bus, on its way to the 1st Ave. terminal, will stop at 8th Ave. and 42d St. and at Grand Central.

Passengers with only light baggage, alighting at LaGuardia for midtown Manhattan, may find it quicker and certainly cheaper to take the city bus from the front of the Administration Building to its terminal at 74th St. and Roosevelt Ave. There they may walk upstairs to an elevated train which brings them to Grand Central or Times Square; or they may walk downstairs to the subway and take an "F" train which stops at Lexington Ave. and Fifth Ave. on 53d St., and at 50th, 42d, and 34th St. on 6th Ave. (Avenue of the Americas). The city bus fare is 13¢, the elevated or subway fare 15¢, a total of 28¢ compared with the airport bus fare of $1.25 plus a taxi fare of 50 to 75¢.—E.H.R.



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Annual Review

Metal Mining

Edited & Compiled by Roger V. Pierce

- Long Hole Drilling
- 4-in. Drifter with Reversible Rotation
- Multiple Stoper Drills to Fan Roof Holes
- Crane and Dropball
- Remote Control Mechanism for Drill Jumbos
- Electrically Operated Rotary Drills
- Drilling Holes with Jet Piercing Hydraulically Operated Rotary Drills
- Larger Trucks, Larger Shovels
- Dragline Conveyor Stripping
- Circular Steel Sets and Concrete
- Rotary Auger Drills Gaining Favor
- Inclines—Truck and Conveyor Haulage
- Hoisting from Open Pit with Hammerhead Crane
- Dual Mounted Drill Machines
- Concrete Headframes and Koepe Hoists
- New Alloy Drill Steel
- Stope and Level Leasing Incentives
- Vertical Shaft Riddell Shaft Mucker
- 32 Mines in Northwest Using Rock Bolting
- Deslimed Sand Filling in Uranium Mine
- 150 hp Slipring Motors on Slusher Hoists
- Stoping Efficiency—122 Tons Per Man Shift
- 36-in. Calyx Holes for Hoisting Shafts
- Circular Concrete Shaft
- Automatic Skip Loading Pan Feeders
- Plastic Hose—Shaft Drain Lines

MINING WAS ACTIVE IN 1953 *despite unfavorable price conditions for some commodities. It was a big year in plant expansion as well as for improvements on existing ones. Many new ideas were developed and others found wider application in the never-ending struggle for more metal output per man hour. A shift in emphasis from increased production to higher efficiency marked 1953, and for this story we turn you over to the 24 mining men from the U. S. and Canada who helped analyze the trends now afoot.*

Methods-on-the-Job

by R. L. Loofbourow

THE degree to which our mineral requirements are being met by mining leaner, more complex or more remote deposits is indicated by developments during 1953. Heavy capital investment, skilled technical advice, planning, and able execution are requirements for the typical venture. Producers, faced with rising costs and with softer prices, are seeking improved mining and recovery.

Developments in production of iron ore are typical of the course being followed in metal and nonmetal mining. Iron ore development in the U. S. is concentrated on the spectacular work with Lake Superior taconite, while in Canada new production is expected from Labrador and output from Steep Rock, Algoma, and Newfoundland is being increased. Shipment of iron will soon be made from Venezuela.

Sizable underground construction projects completed during the year or nearing completion embrace notable development programs such as that of Climax Molybdenum Co., defense installations, underground storage for propane, and power projects such as the tunnels at Niagara and Kitimat.

High labor cost and the need to handle large volumes of rock efficiently have continued to be the main spurs to more and still more mechanization. This is doubtless most noticeable in North America, but is distinct in South Africa, for example, where many mines are operating with 65 pct of what was considered their normal complement of labor.

Exploration Drilling

At the Diamond Drilling Symposium sponsored by the University of Minnesota Center for Continuation Study the following topics were prominent:

1—The desirability of using compressed air or natural gas for cooling and clearing the hole is governed by local conditions but all agree that it is difficult if ground is damp.

2—A camera for photographing the inside of 3-in. holes was described by Robert H. Nesbitt of the U. S. Army Engineer Corps.

3—Most participants in a discussion of diesel power for diamond drills believed it more economical than gasoline even considering first cost and weight of equipment.

4—Research and limited trial of oriented diamonds in bits seems promising but the benefit which may be obtained by the average drill operator is controversial. At least there is substantial interest and broader trials are in progress.

In drilling holes as deep as 200 ft on the Colorado Plateau, longhole percussion drills have been extensively used to supplement diamond drills.

Blasthole Drilling, Short Holes

In stopes and to a lesser extent in development, airlegs continue to displace mounted machines. Tungsten carbide tipped alloy steel is generally used in compact rock, detachable bits set with carbide are more likely to be used if ground is broken, while in soft ground, steel bits are generally favored. Advantages of airlegs are believed to be lower equipment cost, less air consumption, greater portability, greater flexibility and less required operator-skill, which all reduce drilling costs per foot of heading or per ton. An interesting comparison of airlegs vs leyners in large tunnels at Kitimat is given in *Can. Min. and Met. Bull.* October 1953. Under conditions prevailing no strong and consistent advantage in performance for either type equipment was shown.

For a decade the diameter of holes used in development has been reduced until common size is 1 1/16 to 1 3/8-in., which still seems to get enough powder in the hole. Although a prominent manufacturer of airleg equipment is experimenting with still smaller holes to be drilled with ¾-in. steel, it is expected that this trend cannot go much farther without change in blasting practice.

Blasthole Drilling, Long Holes

The already strong position of percussion drilling with tungsten carbide bits and sectional steel was enhanced during the year and this trend is likely to continue unless there should be an unexpected and sharp change in technique and relative bit costs. Diamond drilling continues in places where diamond consumption is small, where diamond drill footage per shift is high, where ground is to some extent broken or where unusually long holes are especially advantageous.

International Nickel Co. and a drill manufacturer have developed a 4-in. percussion drill specifically designed for longholes. Its features are a 6-ft shell under which a specially powerful feed motor is placed, neutral and reverse rotation, semi-integral chuck rod with "O" rings, and a sliding and sturdy centralizer. This unit makes 4-ft rod changes in a 7x7-ft heading. Four-point, carbide-set cross bits, 2 1/8 to 2 1/16 in. are used on alloy steel rods. Upholes to 80 ft and downholes to 120 ft are part of standard drilling patterns. Particulars are given in *Can. Min. and Met. Bull.* October 1953.

At Holden, Wash., Howe Sound Co., uses 70-ft holes regularly but holes up to 86 ft are drilled and blasted without difficulty.

While the diameter of short blastholes has been reduced, the diameter of longholes, whether by diamond drilling or by percussion, has increased. The use of large holes is a real advantage where one or a combination of the following conditions exist: (a) rock tends to break fine, (b) height of stopes or passways helps to break big rock, (c) gathering and transportation can handle big rock, or, (d) secondary breakage is exceptionally efficient.

Drilling Research

Drilling Research Inc. is a nonprofit corporation set up in 1948 by some 40 oil companies to perfect better ways of drilling holes in rock. Many unconventional techniques have been examined. Director J. V. Pennington reports that aside from improvements in present practice, the greatest promise is shown by percussion drilling with frequencies in the order of 300 cycles per second. Blows of this high frequency and correspondingly low amplitude are generated by a magnetostrictive device in the bottom of the hole, supplied with alternating current from the surface. Laboratory tests of this equipment are encouraging and field trials are to be conducted.

Blasting

Igniter cord has been adopted by a number of mines, because of its safety and economy, for drifting and use in some types of stoping. The master fuse alone is spit; if a long interval between spitting and firing is required, a long master fuse is used.

In eastern Canada it is common to drill the center or relief hole of burn-cut rounds with a bit of 2½ to 3-in. diam. This is usually done with a light machine used for drilling small holes in the remainder of the round.

At Mt. Weather the U. S. Bureau of Mines has made further trials of no-cut hole raise rounds using millisecond delays and finds them equally effective, as compared to V-cuts, in breaking, superior in fragmentation, but harder on timber.

The use of short period delays has spread rapidly in quarrying and related construction; it is accepted underground to a more limited degree in stopes and at some mines in drifts. The use of *alternate velocity* loading may be watched as a logical accompaniment of short period delays.

Loading and Transportation

Examples of the growing use of diesels underground are presented in *Mining Congress Journal* January 1953, which cites experience at Idarado, Great Western Sugar Co., and the Bautsch mine of Tri-State Zinc Co. Their safety, flexibility, economy and great tractive effort are emphasized and requirements as to ventilation and protective devices are discussed. Complete conversion to trackless diesel powered equipment (loaders, trucks and propulsion of drilling jumbos) reduced costs 50 pct.

Two new trackless loaders are of special interest underground, the Lorain TL and Eimco 105. The latter may be especially watched because of the fine performances of its ancestors.

Usefulness of compressed air trammers (using air at 100 psi) has been demonstrated at a number

of mines where they have been used for hauling light trips over moderate or short distances.

Shovels, draglines, and trucks for surface operation continue to increase in size; the only limits appear to be the scale of the operation on which they are to be used and requirements for flexibility and selectivity in loading. Where large yardages of waste are to be moved these limits are certainly not oppressive.

Shaft Sinking

Superlative accomplishment in South Africa utilizes double or triple-decked sinking stages, supported from special low geared hoists, which safely allow placing of forms and concrete and in some cases buntons, guides and other permanent shaft equipment while the bottom is being drilled and loaded, large sinking buckets, and a number of fast bucket hoists. Ample ventilation, well-supervised large crews and thorough planning, scheduling, and integration of all activities are assisted by experience gained in sinking numerous large, deep shafts. Within the last few years attention has been given to mechanical loading while the best features of earlier practice were retained. The latest record is 585 ft sunk in May 1953 at Vlakfontein No. 2 Shaft which is 24 ft 1-in. diam inside concrete lining which is complete except for open rings on 12 ft 6-in. centers in which buntons will later be set. Muck is loaded by a 1 ton capacity, six prong orange peel *grab* which is opened and closed by an air cylinder. The grab travels on a radial monorail slung under the lowest deck of the sinking stage with power to move the crawl radially and to rotate the monorail to traverse the entire bottom. Buckets hold 90 cu ft and are hoisted at 3000 fpm for rock. The grab is said to load 5 tons in 3 min and to handle 100 tph.

Rock Bolting

It may be agreed that rock bolting is no panacea, but it has wide application. Rock bolts have proved themselves in hard and soft rock, in uniformly bedded sediments and in irregularly jointed igneous rock. They have been used for permanent support and have shown promise for temporarily holding stope walls. They may be used with washers, channels, mesh, or timber.

Variations of rock bolting include wood bolts used at Day Mines, roof *sewing* as reported from Norway (actually a combination of grouting and tying rock together with small diameter cable) and a somewhat similar use of cable to hold timber as practiced at East Malartic and Quemont in Quebec.

Whatever the application, rock bolting is only as effective as the tension maintained in the bolt. The USBM, at least one manufacturer, and some mines are studying performance and simple means of testing tension.

Block Caving

Block caving, with various forms of longhole stoping, is a prime bulk mining method. For this reason it has spread to the Coeur d'Alene, Butte, Sudbury, Michigan, and the asbestos mines in Quebec. An unusual application of block caving was made by Inspiration Copper Co., in caving a small block into the bottom of its Thornton Open Pit (See MINING ENGINEERING, Sept. 1953, p. 922) to create an oversize orepass. Objectives were to make available for mining a substantial tonnage that would have been overly difficult to haul from the pit directly, to decrease cost of mining the remainder of the pit ore, to crush ore in the passway, and make use of existing idle underground facilities.

Adirondack District, New York

by W. J. Linney and W. A. Blomstran

Longhole Drilling

Republic Steel Corp., Port Henry Div., has accomplished advances in longhole drilling with coupled rods through the use of a new 4-in. drifter equipped with reversible rotation and a special rod-holder attachment. The reverse rotation makes it possible to quickly disconnect the rods when adding sectional steel. The shank stays in the machine while changing rods. With the feed motor mounted under the shell on this machine a minimum of space is required to make a 4-ft steel change. Carbide-insert bits drill 2-in. holes up to 100-ft deep at almost any angle in relatively coarse, crystalline, magnetite ore. The sectional rods used are alloy steel, heat-treated over the entire length.

The usual open stope, sublevel ring-drilling mining method is used where the orebody is suitable for gravity mining. Another application of longhole drilling is in the recovery of ore from pillars.

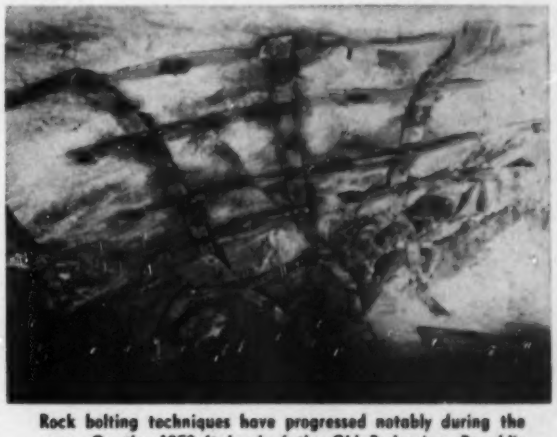
In blasting these ring-drilled sublevel stopes, a recent shot used 18,000 lb of explosives fired by millisecond delay caps. Large shots, using the fast caps, have worked out well with a minimum of vibration, and causing no damage to other areas.

Since the change to carbide bits at the Lyon Mountain mine the main trend has been to longhole drilling out of sublevels for increased safety and efficiency.

Communications

A communication system from cage to shaft house and to hoisting engineer has been in service for a year with satisfactory results from the standpoints of safety and economy. The carrier current system is used, with the hoisting cable as one circuit and a No. 12 copper wire along the slope track as the other. The No. 12 copper wire is connected so that in case of derailment or trouble along the slope interrupting the circuit, an emergency alarm signals the hoisting engineer. A vertical shaft installation uses the hoisting cable for the carrier current and the steel headframe for the pickup loop.

Each set consists of a transmitter receiver unit operating on 163 kc. The cage set is powered with a 6-v battery which also furnishes lights and horn on the cage. The surface equipment is operated on 110-v ac current.



Rock bolting techniques have progressed notably during the year. On the 1950-ft level of the Old Bed mine, Republic Steel Corp., Mineville, N. Y., lacing between roof bolts with ¼x6-in. steel strips is used to support rock between bolts.

View of U. S. Steel's Pilotac experimental mine near Mountain Iron, Minn., which will supply taconite formation for beneficiation and agglomeration. In the background drills are putting down 35-ft blast holes.

Underground mining in Michigan's Upper Peninsula is leaning to rotary auger drills as contrasted with percussion drills. Drilling speed is approximately twice that of percussion drills and maintenance is less.

Roof Bolting

Roof bolting experiments have been made using a new type wedge-head bolt and expansion shield. The type formely used were split-end bolts 1½-in. diam, driven into the hole onto a steel wedge. This type pulled loose at 2-ton tension. The new type ¾-in. high carbon steel bolts broke at 18 tons without the anchorage failing in any case tested to date.

A multiple arrangement of stope drills is contemplated on the drifting jumbo so roof-bolt holes can be rapidly drilled while making a regular drift round. Bolts in some areas are connected from bolt to bolt with ¼x6-in. strap iron with slotted holes to help support scaling rock between bolts.

St. Joseph Lead Co. is operating the Edwards and Balmat mines in St. Lawrence County, N. Y. These are 400 and 1800-ton producers, respectively. Recent developments in mining, such as roof bolting, tungsten carbide bits, and longhole drilling have found their applications in these operations and have proved a boon in helping to offset rising labor and material cost. A diesel locomotive recently put into operation in the Balmat mine for a 1-mile underground haul has been highly satisfactory.

Design and operation of both St. Joe mills is aimed at increasing recovery of all products at a minimum cost. The 3-stage crushing plants have been replaced by 2-stage crushing with gearless crushers, to produce a finer product with less power, labor, and maintenance. Increased storage capacity for crushed ore (1½ days supply) provides a period for mill repairs plus steadier operation.

Lead recovery is kept at an optimum by floating between the two grinding stages. Zinc recovery has been raised in the past year by subjecting the hard-to-float zinc in the tailing to a completely separate scavenger circuit.

Dam building in the summer months has been aided by small cyclone thickeners along the tailing line. Use of items such as silicon-carbide pump parts, rubber-lined pipe and nylon filter-cloths has reduced maintenance costs.

Dropball Crane

In the mining operation at **National Lead Co.'s MacIntyre Development** the rubber-tired crane handling a dropball has continued to be the most interesting innovation. (See MINING ENGINEERING, April 1953 p. 379.) This Osgood 1½-yd Mobilcrane has made the dropball application economical where a conventional crawler-mounted crane could not because of the traveling distances. Maintenance costs have been exceptionally low and availability high.

Following the lead of the Kaiser Steel Co.'s California iron mining operation, MacIntyre installed 1-in. thick cast manganese steel Hadfield type liner plates in a 15-ton rear dump Euclid truck. The plates were bolted in place. Wear characteristics have been excellent and no trouble has been experienced with the bolts. Chief disadvantage of such plates is the dead weight added to the truck.

New Plant Operating

Cabot Carbon Co., Carbot Minerals Div., has just put a new wollastonite plant at Willsboro, N. Y., in operation. This $1 million plant will produce 60,000 tons annually of several finished grades of wollastonite for paint and ceramic industries.

The wollastonite, associated with magnetic garnet, is mined by open pit methods from a 30 to 70-ft thick vein containing about 15 million tons. After a 1½-mile truck haul, the ore is crushed, beneficiated by magnetic separation, ground, and bagged for shipment.

Barton Mines Corp., North Creek, N. Y., is using a 22B Bucyrus-Erie crane with a 4600-lb dropball for breaking large boulders in the quarry. This has practically eliminated secondary blasting.

Lake Superior District

by E. P. Pfleider

$1 Billion Expansion

The Lake Superior iron ore industry made new production and shipment records during 1953. While setting these records, it also moved ahead on many new development fronts. The major development underway is, of course, that of the taconite industry. Pilotac, **Oliver Iron Mining's** new pilot plant operation rated at 500,000 tons of taconite concentrates annually, joined those of **Reserve Mining Co.** (300,000 tons) and **Erie Mining Co.** (200,000 tons). Meanwhile, construction is continuing on the full scale plant of Reserve at Beaver Bay, and preliminary contracts have been let for the building of the Erie project at Aurora. Each of these plants is being designed for an ultimate annual production of 10 million tons of agglomerated concentrates. Other major developments along the ranges include:

Cleveland-Cliffs Iron Co.'s Humboldt project on the Marquette Range is scheduled to start production of 200,000 tons of concentrates annually in

White Pine Copper Co. is scheduled to produce 12,500 tons of 1.1 pct copper ore daily. Mining method will be a modified room-and-pillar system with Joy loaders and 18-ton diesel shuttle cars as shown operating in drift M-1 of the mine.

View of the White Pine surface installation under construction. Shown are transfer stations 1, 2, and 3 with conveyors leading to the coarse and fine ore bins. A portion of the shop facilities are on the right.

early 1954. It features flotation of specular hematite and is the first of several similar low grade operations being considered on the Michigan ranges.

Inland Steel Co. has let a contract for the dredging of some 160 million cu yd of silt from its orebody at Steep Rock Lake. The $25 million job will employ 2 dredges pumping 60,000 gpm removing about 5000 cu yd per hr. The dredging alone will require 5 years. Ore production is scheduled by underground methods starting in 1960 at the rate of 3 million tons annually. Reserves are estimated at 50 million tons.

Steep Rock Iron Mines shipped the first ore from the Hogarth mine, its second open cut operation along the ore trend. Some 40 million cu yd have been dredged in the past 3½ years to uncover the orebody.

Mining activity expanded to the low grade orebodies of the extreme western end of the Mesabi range, where the West Hill, Greenway, and Tioga mines are either in production or under development. The Tioga operation, located near Pokegama Lake in the vicinity of Grand Rapids, will be the first Mesabi producer west of the Mississippi River.

White Pine Copper Co.'s project in the Michigan Upper Peninsula, a $70-million dollar investment, is scheduled to produce 75 million lb of copper annually, with a daily mine production of 12,500 tons of 1.1 pct copper ore. Access to the mine is by truck through a concreted tunnel having two 12-ft roadways and a 10 pct slope. Ore transportation is by 54-in. belt conveyors up a 11 to 16 pct inclined drift. The modified room and pillar mining system will feature the use of Joy loaders, special drill jumbos, and diesel shuttle-car trucks of about 18-ton capacity.

These major undertakings, as well as many other significant developments, will represent an ultimate expenditure in excess of $1 billion. They are the answer of the Lake Superior mining industry to the inroads of foreign ore competition.

Continued Improvement & Expansion

The year 1953 has not been one of startling new innovations insofar as mining techniques and equipment are concerned. Rather, it has been one of continued improvement and expansion of the established trends.

Open Cut Mining—Blast hole drilling and secondary breaking have received much attention. A concerted effort is being made by manufacturers to develop drills that can replace the old churn drills for many jobs. Units being tested include jet piercing, pneumatic percussion type drills, hydraulically operated churn drills, and rotary drills. Some encouraging results have been obtained with hard insert rotary bits drilling 6 to 8-in. holes in taconite and granite. The use of dropballs is receiving increasing favor for secondary breakage.

The trend to larger trucks and shovels continues. The 34-ton truck is most popular, and a 50-ton end-dump unit has been on trial. Rubber-tired tractor-trailer units that carry 60 tons or more are being considered by taconite operations in preference to rail operations for the pit to crusher haul. The larger trucks make possible use of larger shovels, up to 10-cu yd capacity but generally of the 6 to 8-cu yd size. The contractors, in particular, like the straight diesel powered shovels of 5-cu yd size with torque converters.

Dragline-conveyor stripping, as well as inclined skip hoisting out of deep confined pits, continues to win favor.

Underground Mining—A swing toward the use of lower cost, less selective types of mining methods has continued. There have been improvements in the technique of the block caving and a more general acceptance of that method on the Iron Ranges. Much thought has been given to the establishment of simple concentrating units at underground mines, thus permitting the economic production by low cost caving methods of marginal ores lying over and around the high grade bodies. Furthermore, such a treatment plant would solve the dilution problem always present in certain portions of block-caving production of the high grade bodies. Design and use of steel supporting sets, as well as of concrete underground has improved—particularly in the transfer drifts.

The trend has been toward rotary auger drills as contrasted with percussion auger drills. Drilling speed is approximately twice that of percussion drilling and maintenance is considerably less.

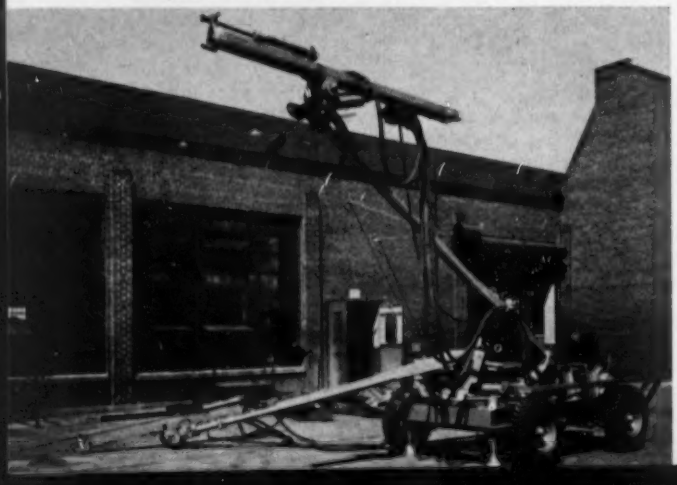
There has been a gain in popularity of underground crushing and conveyor belt haulage, with the following advantages claimed: secondary breaking by drills eliminated and cheaper faster transportation where orebodies are located far from hoisting shaft. The Koepe hoisting system, popular in Germany and Sweden, is planned for the Cliffs Shaft mine.

Whereas the percentage of ore mined by underground methods continues to decline in Minnesota because of the relatively shallow depths of the de-

Fast mobile drilling equipment is a necessary feature of the White Pine operation. Shown here is the Joy Drillmobile.

Drilling equipment is in an important transition. One trend is toward light jackhammers on pneumatic legs for drifting and stoping. Above, on the 4850-level of the Homestake mine this type of equipment is shown in an 8x8-ft arch drift.

New experimental remote-control jumbo built by Gardner-Denver, (above and below) is being used experimentally in the Birmingham iron ore district. It mounts two chain-fed drifters that drill full round depth with one steel. One operator runs both machines.



posits, this form of mining is expanding in Wisconsin, Michigan, and the iron belt of Ontario. The new Mather "A" and "B" shafts of Cleveland-Cliffs on the Marquette Range are approaching maximum capacities as the largest producers in this underground mining belt. Pickands, Mather is sinking its new Peterson shaft on the Gogebic Range, and M. A. Hanna has its Cannon shaft on the Menominee Range advancing in ledge after a most difficult job of driving through quicksand and boulders under air with a closed caisson. (See MINING ENGINEERING, Aug. 1953)

Although these new major producers are being developed for hoisting through vertical shafts, because of their appreciable depths, there is a definite trend toward the use of flat slopes. White Pine was mentioned earlier, and the Helen mine on the Michipicoten Iron Range in Ontario and the new underground development at Steep Rock feature block caving, underground crushing, and belt conveyor hoisting through inclines.

The problem of drilling and breaking of rock is receiving much attention in this area, as it is throughout the country. Longhole drilling with percussion units, using sectional rods and tungsten carbide bits, is gaining in hard rock areas. The air leg and light drill are being used more widely for the shorter holes. It is expected that rotary drilling will continue to make further inroads for blast holes in the softer rocks.

Prominent operators were questioned as to paramount needs of the industry for cutting mining production costs, apart from having a contented working force, at somewhat stabilized conditions. Invariably they replied, "Stronger and more abrasion resistant equipment to withstand the terrific abuse of working with hard heavy ores." The general feeling, of both open pit and underground managers, is that much of the available equipment is designed for the handling of coal or lighter construction materials. It is hoped that there may be continued development of tires to carry larger load limits and to withstand greater impacts.

Birmingham District

by P. G. Cowin

Remote Control Jumbo

During 1953 important developments in the Birmingham district have been made in drilling methods in the underground iron ore mines. Experiments are still in progress in the use of rotary drills for small and large hole drilling. Developments have been made in the use of remote control mechanisms for percussion-type drill jumbos.

Holes up to 8-in. diam have been drilled on an experimental basis in semihard iron ore by means of an air motor-driven rotary drill. Penetration rates have averaged 4 to 5 in. per min for 8-in. holes in iron ore as well as limestone formations. In order to obtain increased depths of cut, the use of one large hole as a reliever in a burn-cut round was tried. It has been possible in this experimental drilling to consistently increase depth of drill rounds from 7½ ft to depths of 16 ft in faces 12x22 ft.

Test work with an electrically operated rotary drill has been in progress for drilling 1⅜-in. holes in limestone and semihard iron ore. Initial tests resulted in penetration rates from 3 to 9 ft per min using various types of carbide cutting bits.

Two manufacturers have designed drill jumbos for remote control drilling; one type actuated by a hydraulic system, the other, by individual air motors. The experimental drill jumbos mount two chain-feed drifters capable of drilling the full depth of the drill round with one steel and the operation of both drills can be controlled by one operator.

Developments in underground haulage during the year have resulted in the installation of automatic, plug-in type, trolley relays for operation of block signals. The plug-in feature makes it possible to quickly replace faulty relay units. Also, time relays have been introduced for the operation of derail switches as a protection to the haulage system from runaway locomotives. The time relays insure that a locomotive is operated under control and at proper speed in order to actuate the derail switch.

In the field of mechanized mining, diesel-electric shuttle cars have been introduced both in underground limestone and iron ore mining operations, resulting in benefits in the improved length of travel from loader to dump point.

Western South Dakota

by Wm. C. Campbell

Homestake Mining Co. and **Bald Mountain Mining Co.** were the major gold producers in the area during 1953. Production at Homestake will show an increase over the year 1952, the gain for the first three quarters was about 13 pct above 1952.

The increase in tonnage was accomplished in spite of the mill being remodelled during the year, and production had to be curtailed while change-overs were being made.

Increased production in the mine is due to an increase in manpower and to increased efficiency through improvements in equipment and mining methods. All stoping is now done with air leg drills using 1⅜-in. carbide bits. Cut-and-fill mining, with a minimum of pillars, is replacing shrinkage stopes and square-set pillars. Rock bolting is being used with very good success in drifts to eliminate timber, and in the stope walls.

A project is underway to start development work below the 5000-ft level. An underground shaft will be started to be connected to the present Ross and Yates shafts by a haulage drift on the 4850-ft level. About 5400 ft of the drift has been driven to date, entirely with air leg drills. The drift is 8x8 ft with arched back. The rate of advance has been 8 ft per shift; or 16 ft per day for two shifts.

During 1952 a rather extensive exploration program was planned and started by the Bald Mountain Mining Co. The object of the program being to test new undeveloped areas for future production.

The most important part of the proposed work was the reopening and rehabilitation of the Decorah mine, closed since 1919, and the driving of a 1000-ft crosscut east of the old workings. At present, 60 pct of this work has been completed.

Recently the property and facilities of the Black Hills Tin Co. at Tinton, S. Dak., were taken under lease by the Bald Mountain Mining Co. The orebodies consist of pegmatite dikes composed of fine grain quartz and spodumene with small amounts of feldspar, columbite-tantalite and mica. The ore is mined by open cut methods and it is treated on the property in the 50-tpd mill producing a spodumene concentrate.

Exploration for uranium continued in the Black Hills area of South Dakota and Wyoming during 1953. Airborne and ground prospecting was carried on by the Atomic Energy Commission, the Homestake Mining Co., and various other private groups. New discoveries have been reported west of Belle Fourche, S. Dak., and in the New Haven area of Wyoming, where exploration is now in progress. The Black Hills uranium occurs as carnotite in the Dakoto and Lakota sandstones.

Tri-State District

by S. S. Clarke

Production in the Tri-State district will be about 45 pct lower than in 1951 and 1952. This drop is partly due to low metal prices and a strike at **Eagle-Picher** which was called June 20, 1953 and is still on. The Ballard mine of the **National Lead Co.** shut down about the middle of November.

At the outset of the year, considerable interest was shown in the possibilities of open pit mining in the Joplin area, with four open pit mines in operation and two in various stages of development.

The decline in metal prices, coupled with lower grade of ore, caused all to close except the Quick Seven mine, a joint venture of the **American Zinc, Lead & Smelting Co.**, and **Brown & Root Inc.**

The operations are rather unique. Stripping with a Monighan dragline, using shovels and trucks in the pit, and hoisting ore to the washing plant by a hammer-head crane, is its mining method.

Several small companies and individual producers who shipped to the Central mill have been forced to shut down by the strike at Eagle-Picher.

Rock tons hoisted for the year will be approximately 3.5 million tons as compared with 6.0 million in 1952. If operations are partially resumed in 1954, the output will not equal 1952 unless there is an increase in metal prices.

The major improvements introduced this year at the Ballard mine of the National Lead Co. were a Heavy-Media cone and cyclones in the concentrator. A long haulage drift to the Swalley acreage was also driven.

Eagle-Picher is constructing a roasting and sulphuric acid plant at the Galena, Kan., smelter, to be in operation in 1954.

Southeast Missouri

by Elmer A. Jones

The completion of **St. Joseph Lead Co.'s** Indian Creek plant, 11 miles northwest of Potosi, Mo., late in the year is big news in this district. There are several new operating ideas used in this plant that are firsts for the area:

1—A circular, concrete lined shaft with all steel dividers, guides, manway and ladders. Steel pipes imbedded in the concrete wall serve for compressed air, water line and electric feeder cables. One compartment is large enough to lower shuttle cars, ramps, and other trackless equipment. 2—Automatic skip loading with pan feeders conveying ore from pocket to weigh hopper operating electronically. 3—Drill jumbos using indexing device to provide pattern drilling. 4—Loading with scraper mounted steel ramps on rubber tired chassis with electric drive motors.

Continued conversion to trackless haulage of ore is another feature of this year's progress. Diesel trucks and Tournarockers are being used successfully in newer mines with larger drifts. In the older parts of the Lead Belt a smaller truck, 2-cylinder

Surface installation of St. Joseph Lead Co.'s Indian Creek plant near Potosi, Mo., features circular concrete lined shaft and automatic skip loading. Steel pipes embedded in the concrete carry compressed oil, water, and electricity.

One of the design features of the circular concrete shaft at Indian Creek is a compartment large enough to permit lowering shuttle cars and other equipment without disassembly. A shuttle car is being prepared for lowering.

In the Tri-State district considerable interest is being shown in the possibilities of open pit mining to decrease costs. At the Quick Seven mine a hammerhead crane is used to hoist ore out of the pit, above.

with 6-ton dump body is being tried. This unit has a favorable ratio of empty weight to load of 4 to 6, and an overall height of only 5½ ft. It is 6½ ft wide, and 18½ ft long, and can operate at top speed of 25 mph with enough power for 15 pct grade.

Underground crushing at Hayden Creek mine is another first in the district. A Holland 40-in. impact crusher is reducing mine ore to —4 in. before it is conveyed to the skip pocket.

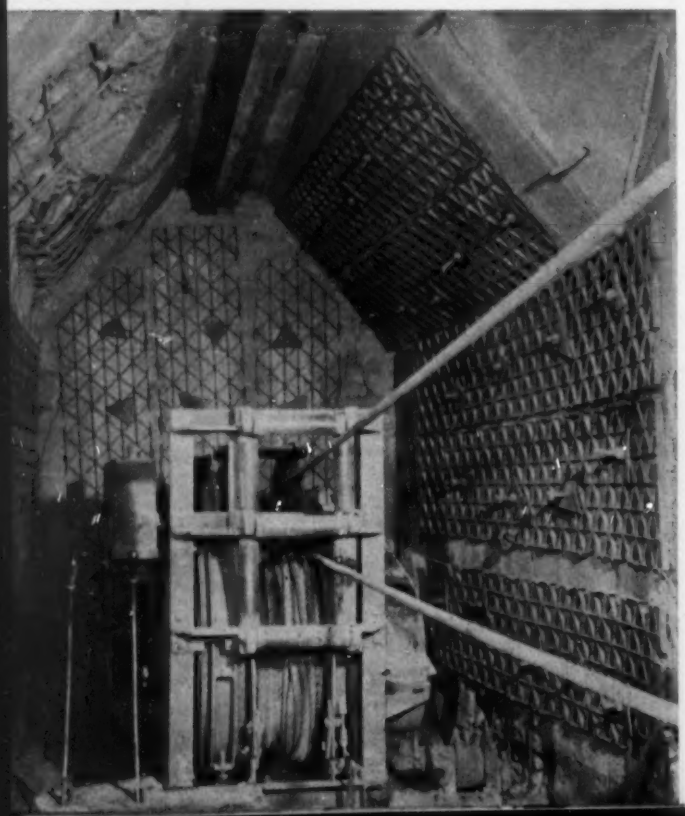
Operators feel that the machinery manufacturers should strive for more rugged loading and hauling equipment to reduce maintenance, and for units that operate in lower and narrower headings.

Developments at Climax

by Robert Henderson

The cost of driving and concreting slusher drifts has disturbed the **Climax Molybdenum Co.** mine management for a number of years. Considerable overbreak has resulted from driving these slusher drifts 9x12 ft, especially in fractured ground. The concrete required to replace the overbreak has exceeded the theoretical amount by as much as 100 pct.

Recently pilot headings have been driven and the finger raises are then driven from the pilot bores. Drifters are set up in the finger cut outs and ring drilling is done from one finger cut out to the next with holes approximately 20 ft long. These holes



Left: Slusher hoist installation developed at Climax Molybdenum in Colorado features an overhead monorail for removing the hoist or its components for repair. Note rock bolted steel mat for supporting damaged concrete.—Below: Diesel locomotives are now moving underground in the Coeur d'Alene district, this 10-ton locomotive being the first step in the trend.

An outstanding development in the mining of uranium on the Colorado Plateau has been the use of 36-in. Calyx drill holes for hoisting ore from depths up to 125 ft. This has been effective in reducing costs on the Plateau.

are drilled to break the slusher drift to the 9x12-ft size required.

This method, although more costly from an excavation standpoint, holds promise of reducing the total cost of these drifts.

War surplus landing mats and roof bolts have been used recently in an attempt to hold the concrete in badly fractured slusher drifts.

Occasionally point pressures are transmitted to the slusher drifts and the concrete is badly broken. In many cases, concrete and rock are displaced and repair work has to be done. Previously, the broken concrete was replaced with new concrete. Use of landing mat held in place by roof bolts seems to have solved this problem, or at least delayed the new concreting for several months.

In cases where it becomes necessary to replace fractured concrete, grout has been pumped through drill holes into the fractured ground in back of the old concrete. This grout holds the fractured ground while new concrete is placed.

In the slusher hoist cut outs, 5x10-in. 35-lb I-beams are installed in the back from the discharge opening from the slusher drift to the end of the drift. Crawls are placed on these beams to facilitate the handling of the slusher hoists or parts when installing, removing, or repairing hoists.

The steel aprons on the hoist side of the discharge point are now being installed on a 45° incline. This prevents muck from being piled up in front of the hoists and at the same time gives the hoist operators a view of the cars being loaded, and spillage from loading cars is reduced.

During the last year, 150-hp high-slip motors have been used to power the slusher hoists. Prior to this time, 100 and 150-hp induction motors were used. Use of high-slip motors is not new, and they have been used for many years in slushing operations but these were smaller motors. It is believed that these high-slip motors will reduce costs by decreasing maintenance on motors, hoists, and replacement of cables.

The Colorado Plateau Area

by G. E. Roberts

Uranium mining in the Plateau area is still on the upswing and this year there have been several significant areas developed. Larger and better financed companies are entering the field which should, in turn, greatly stimulate production.

The area of new discoveries is expanding, especially in Utah and New Mexico. More and more orebodies are being discovered in formations other than the Morrison. The old adage, "Gold is where you find it," is beginning to apply to uranium.

The outstanding new developments in this area are:

1. The Mi Vida mine of the **Utex Exploration Co.**, located near Moab, Utah.
2. **Pick Uranium mine**, located near Hanksville, Utah.
3. New Mexico operation of the **Anaconda Copper Mining Co.**, located near Grants, N. Mex.

The most prominent new developments in the mining and exploration methods in this uranium region are the utilization of 36-in. diam calyx drill holes for shafts, and the improvement in longhole wagon drilling. At the **Consolidation Uranium** operation in the Temple Mountain area, 36-in. diam drill holes up to 125 ft in depth are used successfully to exploit the orebodies. In many areas, deep hole (up to 300 ft) wagon drilling is being done at a nominal cost. As many as six 90-ft holes have been drilled in a single shift.

The operators in this area have been open-minded in regard to the application of equipment to mining these orebodies. They are successfully utilizing in underground operations: crawler tractors, small diesel shuttle cars, small diesel locomotives, and other more unconventional mining equipment. However, a low head, self-propelled mucking machine, crawler or wheel-mounted, is the type of machine this industry needs most to improve production costs.

In summary—it would appear that uranium mining is becoming more stable, and yet, still offers a Golden Opportunity for the small operator. It is, at the moment, the Last Frontier of the mining game in the U. S.

Coeur d'Alene District

by Roy G. MacFarland

Bunker Hill & Sullivan Mining & Concentrating Co. is engaged in a deep shaft development project at its Crescent mine. The present 1200-ft shaft is to be deepened 2000 ft and development work carried on from the shaft. By use of the Riddell shaft mucker and pneumatic column mounted drifters, the district's best vertical shaft sinking time is being established. For the month of September an average advance of 9.2 ft per day was maintained. An auxiliary pocket is being established at the 2000-ft level to speed muck handling time and the rate of advance should continue or be bettered.

The use of jackleg type drills is gaining favor in a district. They are being used for general stoping practices, breasting down, drifting, rock bolting and for air, water, and ventilation pipe pin hole support.

Alloy drill steels show good indications for rock drilling in this area. While some drilling is still being done by single pass and multiuse steel bits, the major amount of drilling is with carbide bits. Bit size continues to decrease in many places formerly using up to 2-in. bit gage now down to 1½ or 1⅜-in. size.

Driving the 8500-ft Star tunnel from the Hecla surface plant to the 2000-ft level of the Star mine was to be completed in 1953. This crosscut will speed up materials handling, ore transfer, and getting the men to working places underground. The use of 10-ton diesel haulage locomotives for this job is a first step here in underground diesel operation in this district.

Lower metal prices the past year brought about

At the American Zinc Lead & Smelting Co. operations in the Pacific Northwest the Gizmo has received considerable attention. It has been very effective in increasing tonnage per man shift, serving as a loader and jumbo.

the introduction of a new stope and level-leasing system in several mines. Under this type of leasing both leaser and mine management share net profits after deductions for plant operation and mill charges. The question of more production per employee continues to be one of managements big problems. The apparent unattractiveness of underground mining, plus the loss of previous wage differentials with outside labor has caused mining to lose its attractiveness as a career to young men or engineers. This trend has been felt in the district.

Many viewed the closing of the Morning mine at Mullan with mixed emotions. This property, a steady producer since 1889, was called the world's deepest lead mine since it had been worked from 5500 ft above sea level, to 1060 ft below sea level. Probably the best display of a miner's philosophy was expressed by one old-timer who said, "I've quit lots of mines in my life, but this is the first one that ever quit me."

Montana District

by Robert Weisner

The two items of primary interest in mining at the **Anaconda Copper Mining Co.** properties in Butte this year are the progress made in the development of the Kelley project and the use of push feed drills in development work at the Kelley project and for stoping in the selective mining areas.

The service shaft for the Kelley project has been holed through so that the main shaft will soon be converted from two to four skip compartments for handling ore. Production is now over 10,000 tons and well on its way to the planned 15,000 tpd.

Some concreting has been done in the grizzly drifts which has reduced maintenance and timber replacement. In a continued effort to improve ore handling, work is being done on a slushing system to handle the ore rather than from draw chutes. For this purpose two 50-hp, double drum slushers will be installed soon in the first zone in which it will be tried.

The use of push feed drills was first tried at the Kelley project at the undercut level where they showed definite advantage over development with stopers. Since then, extensive testing has been done on a method of stoping in the selective mining areas which incorporates the use of push feed drills in long flat rounds, rock bolting for roof support which practically eliminates the use of timber, sand filling with deslimed mill tailing, and the use of millisecond delay blasting. Slushing at the present time is done with 15 to 20-hp double drum electric slushers. Work is carried on continually to improve each phase of the mining cycle and results to date are very encouraging. Some drifting and other development work is also done with push feed drills.

American Chrome Co. at Nye, Mont., began work in June at its Mouat property. Production soon reached 500 tpd and work was continued to smooth out both the mining and milling operation. Stoping is principally by longholing using 3½-in. drifters, coupled alloy steel and 2-in. Carset bits. Longholing is from sub-drifts which are at about 55-ft intervals. Some stoping is being done in the irregular or faulted stopes by a shrinking method using both jacklegs and light stopers. All drifting is done with jacklegs using ⅞-in. hexagon alloy steel and 1⅜-in. Carset bits. Development raises are driven with light stopers using jackhammer frontheads. With this arrangement the same steel is used in the stopers as with jacklegs, greatly simplifying drill steelmaking and handling.

Recently, production was increased and it is planned to mine and mill 1000 tpd. An interesting feature of this operation is the 1¼-mile aerial tram which picks up the ore at the mine and delivers it to the mill 2000 ft below.

Victor Chemical Co. completed development work at the Canyon Creek mine located near present operations at Maiden Rock. Development includes a 1000-ft transfer raise and blocking out the orebody. Longhole drilling practice is changing from rotary diamond drills to percussion drills. At present a diesel locomotive is on order for main haulage.

Montana Phosphate Products Co. is testing a push feed drill, carbide bits, and alloy drill steel. Results to date are not conclusive, however, the use of lighter machines and tungsten carbide bits in combination with 16-in. powder has been encouraging.

Fluorspar production in the Darby area is the only major surface operation in the state. Work is being continued by the **Minerals Engineering Co.** on tungsten milling and mining operations at Glen, Mont. Manganese production is continuing at a reduced scale in the Philipsburg area by the **Trout, Taylor-Knapp,** and **Contact Companies.**

Washington-Oregon-Alaska Districts

by Roy Larson

Mining in Washington, Oregon, and Alaska is in a position comparable to the industry throughout the rest of the U. S., mainly the problems are reducing costs and developing new orebodies.

Pend Oreille Mines & Metals Co. recently placed crawler drill jumbos and diesel trucks and loaders

underground. They have changed open room and pillar mining method from scraper to trackless equipment. Eimco diesel loaders, Allis-Chalmers high-lift, and Dart 5-ton diesel trucks are being used. Diesel tractors have been equipped with drilling booms and make a useful and easily handled drilling jumbo. Ore is now crushed underground and elevated to surface by means of conveyor. This trackless mining combined with the underground conveyor system has resulted in a large reduction of mining costs.

In the same area the **American Zinc Lead & Smelting Co.** employs the Hayes Gizmo which combines a drill jumbo, mucker, and haualge equipment in the same unit. Mr. Hayes advises the Gizmo has been under development since 1946. Model IV which is operated with an HD5-F Allis-Chalmers tractor has been in use at the Grandview mine for 23 months beginning in January 1952. During that time 329,-216 tons have been handled and one machine has moved 210,959 tons.

The normal assembly of equipment consists of one Gizmo, used as a self-loading transport and the second Gizmo equipped as a 3 to 5-drill stope drilling jumbo.

Currently, two of these assemblies are used at the Grandview mine on a 100 pct mechanization basis and produces 700 to 750 tpd.

Using the Gizmo self-loading transport, the operator and five drillers produce over 700 tons daily, for a stoping efficiency, in November, of 122 tons per man shift. The entire production crew, including underground and surface employees, exclusive of development, during November was 22, or the production for the month was 35.25 tons per man.

Total mining cost for October, exclusive of development, but inclusive of all other charges, service, underground and overhead, was $1.29 per ton. In both instances there has been a generous increase of production per man shift.

Howe Sound Mining Co., Lovitt Mining Co. and **Goldfield Consolidated Mining Co.** have taken advantage of carbide bits and sectional drill steel for longhole mining. Diamond drill holes are used also.

Open pit mining operations move towards larger mobile equipment in all phases of the work. **Northwest Magnesite Co., American Smelting & Refining Co.**, at Northport, Wash., indicate the trend.

Coal operations in Alaska are at an all-time high for production. Strip mining is employed wherever the method is applicable. Permafrost overburden, as in the Healy River field, is broken and removed by hydraulic methods. Activity and interest continue in a variety of metals with possibilities of developing into producing properties.

Improved explosives and methods of firing have been made available by the explosives industry for a reduction in costs.

Some thought has been devoted to the possibility of an expanding bit which could make a small chamber at the bottom of a drill hole but this may offer little, since drill speeds have been increased. A method of sorting broken rock underground has potential advantages or something might be done with milling whereby ore dilution underground would be less of a problem.

New Mexico Area

by Earl H. Miller

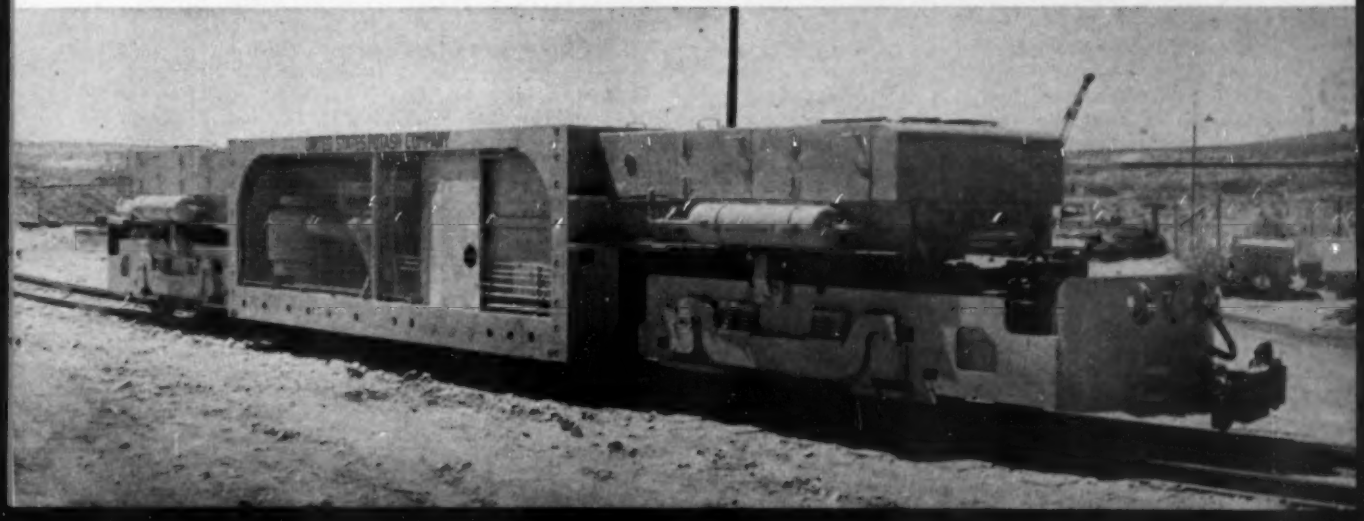
Five companies are operating in the Carlsbad Potash Basin and since potash beds are nearly flat, coal mining equipment and methods are generally used, with all companies striving to improve equipment to adapt it to potash mining.

Continuous miners are being used by three companies for part of their mining. These machines cut potash at a rate of about 60 tph and eliminate many steps of the old method. The continuous miner could be considered an experimental unit with all the potash companies at this time, as there is a large problem of repair and dust that has not been completely overcome.

Waste salt in one mine is being handled in specially designed truck-trailer units using GMC diesel tractors equipped with company designed exhaust scrubbers. These trucks operate at speeds up to 20 mph with a 15-ton load. Ore haulage at this company is to be partly handled with a diesel locomotive of special design, the first unit having been received from General Electric Co. recently. This locomotive is a 40-ton machine carrying a diesel electric generator plant hung between two 4-wheel, 42-in. gage trucks for low clearance. It is equipped with a Cummins engine of 480 hp on the generator and 420 hp on the traction motors. The machine can be operated from either end. Exhaust from this engine is put through a water-filled scrubber to remove objectionable gases and cool the exhaust before it enters the mine atmosphere.

Willys-Overland jeeps equipped with scrubber-

Underground haulage equipment is definitely increasing in size. U. S. Potash Company has placed in operation the first of the new 40-ton diesel-electric locomotives equipped with scrubbers for underground service. Longer trains can be handled faster with this type of equipment.



Crushing and concentrating plant at the Castle Dome Mining Co.'s property. This plant is scheduled to be moved to the new Copper Cities development.

equipped Waukesha diesel engines and Buda Mule diesels are being used for transporting men and supplies.

United States Potash Co. is completing a 15-ft circular shaft, 5½ miles from its No. 1 shaft. The new shaft will be connected with present mine by a double entry haulageway 9x24 ft, with a 33-ft pillar between drifts.

Kennecott Copper Corp., Chino Mines Div., continued to produce copper ore at Santa Rita. Much of the old townsite must be moved to a new location to permit pit enlargement.

Central traffic control for the pit trains is being installed. The new system will be more efficient and also speed up operations. Maintenance of waste cars has been made easier and faster by installation of a larger wheel turning lathe and an automatic welding machine at Santa Rita.

Use of trucks in the pit this year has brought several changes. Euclid trucks powered with 300-hp diesel engines have been acquired. Rated originally at 22 tons, this capacity has been upped to 25 tons by addition of sideboards. The trucks have been used principally for work in the new drop cut—the first to be accomplished at Chino with trucks.

Haulage of waste has been improved by addition of 15 new 40-cu yd waste cars with roller-bearing journals. These cars start easily and handle particularly well at the slow speeds used in pit operations.

There have been several extensive experiments in the Chino mill at Hurley. Among these is the use of cyclones both for thickening and classifying. The cyclones have been used in connection with a successful experiment in regrinding copper middling, the pulp being thickened before grinding.

The year has seen all major lead-zinc operators in Grant County, N. Mex., shut down because of declining metal prices and at present the minimum maintenance is being done.

U. S. Smelting, Refining & Mining Co. at Bayard suspended operations at the end of September, but prior to that an intensive test was underway with jackleg type drills to replace drifters and stopers, particularly in flat lying orebodies. Men using the jackleg drills were under a bonus system and preferred the equipment because it meant greater production and safety. Although primarily used in stoping, the jackleg drills were also used for drift rounds.

American Smelting & Refining Co. at Vanadium operated only 2 months this year. The only innovation of note at this operation was roof bolting, which was termed successful.

Empire Zinc Division of New Jersey Zinc Co. at Hanover suspended production last year but kept a small crew doing routine development work in the mine and on the surface.

Peru & New Mexico Consolidated Mining Co. at Hanover shut down operations during the year except for routine maintenance; prior to that time roof bolting had been tried in the Kearney shaft and similar work was being planned for other spots in the mine.

There has been a substantial increase in uranium mining activities in northwestern New Mexico, with **Anaconda Copper Mining Co.** and Atkinson, Topeka, & Santa Fe Railway Co. undertaking substantial programs of mine development. A considerable number of producers shipped uranium ore to the receiving station operating at Blue Water by Anaconda as agents for the AEC.

Arizona District

by R. I. C. Manning

Continued shortage of experienced miners in 1953, and the prevailing high wages, accounted for the increased mechanization and technological improvement in copper mining. There has been a steady trend, during the last decade, from large-scale underground mining to large-scale open pit mining. In 1940 there was only one large open pit mine operating in Arizona, and the proportion of open pit copper ore production was less than 30 pct of the total copper ore mined in the state. Since then, the number of large open pit mines has increased to six in the state, and the proportion of ore mined to more than 84 pct in 1953.

Shovel and truck operations at the major open pits have called for constant research and testing. All production phases of the operations must continually be improved. Requirements are ingenuity and technological know-how.

Of the five new large copper developments in Arizona, four are to be open pit. Two former underground properties, Inspiration and Ray, are each year increasing the proportion of surface production, and in time will be entirely open pit. By caving a block into the workings of its pit and using the block as an ore transfer, **Inspiration Consolidated Copper Co.** has solved a transportation and sizing problem, making possible a great expansion of open pit methods. In this, the tractor drawn carryall scraper has a very important role. Carryalls have already moved over 3 million tons of material at costs comparable to or lower than for conventional truck and shovel operations. (See MINING ENGINEERING, Oct. 1953, p. 978.)

Kennecott Copper Co. at Ray has been using paper casing for 9-in. churn drill blast holes, and find it effects an economy compared to the use of steel pipe. Kennecott now operates 21 to 34-ton capacity trucks in the pit.

In all the **Phelps Dodge Co.** pit operations, emphasis has been on increased mechanism. Rotary and high percussion drills have been used to supplement the conventional churn drills where ground conditions permit. Large mobile cranes with dropballs are used to reduce secondary drilling and blasting operations, thereby increasing efficiencies and safety. Replacements or new shovels added to the pits have been of increased size, and in one lo-

cation a shovel equipped with a 9-yd bucket is used. In haulage operations, the 25-ton capacity truck with the short turning radius has replaced the larger more cumbersome types.

Diesel locomotives with greater horsepower are being tried out at two pits. The new locomotives are rated at 1750 hp, as compared with a maximum rating of 1500 hp previously employed. Track operations are being somewhat mechanized by the use of fork trucks for the placing of ties on the road beds. Serious consideration is being given to a mechanical tie tamper and other track laying and maintenance devices. At one location a rocker-type loader, similar to those used underground but of much larger capacity and mounted on caterpillars is being tried out for cleaning up of benches with small trucks. All of these additions have provided for increased efficiencies, making it possible to increase stripping ratios so that pit limits can be expanded and lower grade ore mined.

It is expected that the Bisbee pit will be ready for ore production by the latter part of 1954 and that within a few months the concentrator will be up to full capacity of 12,000 tpd. Preparation of the Bisbee pit will require the removal of over 40 million tons of waste before operations can get started.

The Copper Cities mine of **Miama Copper Co.** should be in production by late 1954, and will replace Castle Dome's annual production of 45 million lb of copper.

The Silver Bell mine of the **American Smelting & Refining Co.** expects to commence production March 1954, and within 2 years will attain a daily production of 7500 tons of ore and 7500 tons of waste. From present known ore reserves, this property has an expectancy of 12 years.

Bagdad Copper Co. is spending $14 million enlarging its pit and doubling the productive plant capacity. For the year 1953, Bagdad expects to mill 1,260,000 tons of ore with an average assay of 0.875 pct copper and produce 20 million lb of copper. Over 5 million tons of waste will be moved.

During 1953 Bagdad has put into operation a 6½-yd electric shovel; ten new 30-ton Dart trucks and is experimenting with a Euclid 50-ton truck and a Dart 60-ton truck. As of now, the firm opinion is that the larger equipment, both shovels and trucks, will tend to reduce mining and hauling costs.

The San Manuel project is to be the only large underground operation in the state. Millions of dollars are being spent in preparation of the orebody for underground ore extraction, and when finally in operation it will embody the latest in underground equipment and mining technique. It is planned to mine 25,000 to 30,000 tpd.

In other underground operations in the state, light drilling machines are continuing to replace the heavy, mounted rock drill, and roof bolting is being used to some extent.

Probably the greatest improvement in underground operations is the packaging of mine timbers and various supplies and handling and delivery of these packages by fork trucks to the shafts.

Activity in Mexico

by J. C. Archibald

Mining started off at a high level in 1953 in almost all phases, but by mid-November many smaller lead-zinc operations had closed down, and severe cuts in production had been made by the manganese and fluorspar operators.

Concreting slusher drifts has been simplified at the Jeffrey mine of the Canadian Johns-Manville Co. Ltd., Asbestos, P. Q., by the introduction of sectional-bolted aluminum forms. Sections are light and can be handled by one man.

A very serious accident, suffered at one of the Angangueo mines, Michoacan, was headline news as a number of men lost their lives in a fire that has placed the mine out of operation for an indefinite period.

The Federal Government in July decreed a subsidy, providing for the return of up to 75 pct of direct mining taxes paid by the industry. These are the well-known production and export taxes. This subsidy is applicable only to those companies which pay less than 200,000 pesos a month in taxes. The subsidy is so scheduled that the 75 pct maximum is returned at zero taxes, and tapers to no subsidy at 200,000 pesos.

Relaxation in the demand for manganese has caused Mexican producers to curtail operations. U. S. consumers are now reportedly requesting a 43 pct product with no more than 10 to 13 pct combined SiO_2 and Al_2O_3, and large contracts for low grade manganese awarded by the U. S. have been the only stabilizing influence in that field. The relatively new find at Autlan, Jalisco, was purchased by a new company.

Fluorspar mining was restricted during the year, and only the higher grade producers continued. Some acid grade fluorspar was being made at a sink-float plant at Muzquis, Coahuila. The new **American Smelting & Refining Co.** plant in Coahuila was also in production.

The jackleg drill is becoming increasingly popular, but not too much heavy equipment is being put into mines in Mexico, other than **Anaconda Copper Mining Co.'s** operation at Cananea.

Eastern Canada

by C. D. Borror

Drilling

Copco flexible steel up to 24 ft long is being used with jackleg machines at **Sigma Gold Mines Ltd.** and warrants further tests. This steel was used in the undercutting at the Jeffrey mine, but because of the 6-ft undercut drifts, a 10-ft length was found difficult to use.

The Ingersoll-Rand X-L bit was tested and showed considerable saving in cost at Malartic Goldfields mine. It is planned to use this type of bit in future mining operations. This type of bit is also used at the Mindamar mine, Cape Breton, Nova Scotia, with satisfactory results.

Rock bolting of an ore pass at **Quemont Mining Corp.** has been done in an arching pattern. The results have been satisfactory after 9 months in use.

Rock bolting in the walls of an open stope is being done from the sublevels. Twelve-ft split-wedge bolts with countersunk washers and nuts are placed in the walls sublevel elevations. Solid mild steel rods, 12 and 20-ft long are placed in down holes filled with a cement slurry.

The 10-ton capacity Kimberly ore skips were replaced at the Jeffrey mine of the **Canadian Johns-Manville Co.**, Asbestos, P.Q., by the automatic bottom-dump 252-cu ft Anaconda skips.

For underground and surface concreting, a surface central concrete mixing plant has been placed in operation at Jeffrey mine. The concrete is delivered directly to Press-Weld placers, which push concrete through 6-in. pipe into concrete forms underground 2000 ft away.

Forms for concreting in the slusher drifts and draw points at Jeffrey mine are made of bolted aluminum panel. On the haulage drifts arched aluminum panels and trusses are used and are moved by a dolly on the permanent mine track. Similar forms are in use at the **Johnson Co.'s** mine, Thetford Mines, P.Q.

As an addition to the concrete mixture, the C-4-C Celite is being used with gratifying results.

Undercutting the blocks at the Jeffrey mine with diamond drills has been replaced with jacklegs and sectional drill steel with chisel and detachable cross bits.

The Riddell mucker is being used at the Jeffrey mine in the sinking operation of No. 2 Main Shaft, 14 ft x 18 ft 6-in. inside timber.

A new type of 150-cu ft gable bottom mine car is being used at the Johnson Co.'s mine for ore transportation underground.

Western Canada

by L. T. Postle, W. S. Jewitt & E. C. Roper

The most important development in western Canada was the inauguration of uranium production at Beaverlodge by **Eldorado Mining & Refining Ltd.**, a Crown company. Much information about the new project is classified. Mining methods for the narrow veins are either open stull or shrinkage stoping, while the wider orebodies are mined by cut-and-fill stoping. Plans are currently well advanced to replace gravel fill with deslimed tailing.

Most of the small lead-zinc mines in British Columbia have been closed down due to low metal prices although operations have been continued at the Kimberley mine of the **Consolidated Mining & Smelting Co.**, and a few of the smaller mines.

There have been no radical changes in mining techniques reported. The drift towards jackleg drilling with light-weight drifters and integral carbide tipped steel has continued, although some mines are still using heavier equipment. There has been a decided switch from diamond drills for blast hole purposes in the larger orebodies to percussion drilling using jointed rods, 4-in. machines, and a detachable carbide bit. Holes as long as 150 ft are being drilled successfully and economically.

Sullivan Mine—Kimberley

Open pit operations were initiated in 1951 to recover a large relatively low grade orebody located near the original outcrop. Stripping of the gravel and quartzite overburden was originally done by contractors but actual mining operations are carried on by **COMINCO.** Drilling is done with five wagon drills using carbide-insert bits. To date the operation has averaged about 200 ft per machine shift and the yield has been 3.3 tons per ft drilled. Benches are 30 ft high and holes are spaced at 9-ft centers with 7-ft burden. Cut holes are spaced at 5 ft with 5-ft burden. Holes are loaded with 1½-in. powder and millisecond delay detonators are used. Powder consumption is about 0.35 lb per ton. Broken ore is picked up with a 6½-cu yd electric shovel and hauled in 7 to 9-cu yd diesel trucks to a transfer raise in the centre of the pit. From the transfer raise it enters the regular underground haulage system for transportation to the concentrator.

Ore from the open pit supplies about one third of the total feed to the Sullivan concentrator, the balance being supplied from underground operations. Underground production is obtained from pillar recovery above the 3900 level and regular sublevel blast hole stoping below the 3900 level.

Surface gravel and sand are used for backfilling the large open stopes above the 3900 level, but in the newer stopes below the level, float rejected from the sink float plant mixed with about 4 pct iron sulphide concentrates for a cementing agent is being used. Special ventilation provisions are necessary to take care of the gaseous products of the oxidation process but on completion of the reaction a very satisfactory fill is obtained.

The **Bluebell Mine** is located on the east shore of Kootenay Lake, about 6 miles north of the junction of the main lake and the west arm.

It is one of the oldest lead and zinc producers in the Province; its production history dates to 1895.

The mine lay dormant from 1927 until 1948. Diamond drilling and underground exploration at this time developed sufficient ore to warrant building a 500-ton mill. Power was brought to the property from the West Kootenay power plants, by a branch transmission line from the West Kootenay to Kimberley power line.

The mill and power line were completed, and the mine went into production in April 1952 at the rate of 15,000 tons per month, since raised to 18,000 tons.

The ore occurs in irregular bedded deposits and in cross fractures in a limestone bed which outcrops over a length of 1 mile across the Bluebell Peninsula. The limestone bed is 125 ft wide, and dips at 35° toward and under Kootenay Lake. Wall rocks are argillaceous quartzite and quartz mica schist, fractured and slabby in some localities.

Due to the relatively weak hanging wall, flat dip and irregularity of the ore shoots, as well as proximity of the lake, the larger sections are mined by horizontal cut and fill stoping. The narrower sections are mined in the open. No timber support is required, but roof bolting is used where necessary. Gravel is trucked 1½ miles for use as fill. Experiments are being carried on with deslimed tailing for fill.

The mine is down to the 375-ft level, and the main shaft is being sunk to the 675-ft level. At present the workings make 1100 gpm. Provision is being made to handle 3000 gpm.

Production at the **Con Mine** in Yellowknife was increased from 350 to 450 tpd during the past year with only very minor changes in the mill. Underground, preparations are being made for production from the recently developed ore in the Campbell shear. The trend in mining is towards lighter equipment with the use of smaller drills mounted on jacklegs and using tungsten carbide tipped steel. The increased use of slushing equipment has also proved economical.

Tulsequah Mines

Operations continued at **Tulsequah Mines Ltd.** located in north western British Columbia about 30 air miles from Juneau, Alaska. Production was started in 1951 when the gold flotation mill of the Polaris Gold Mines Ltd. was leased and modified to treat the complex gold, silver, copper, lead, zinc ores of the company's two mines, the Big Bull and the Tulsequah Chief located nearby. The initial production rate was 250 to 300 tpd and in 1952 an expansion program was started with the result that early in 1953 the milling rate was raised to 500 tpd.

To date the bulk of the tonnage has been obtained from the Big Bull mine where both open pit and underground mining methods are in progress. In the small pit a ¾-cu yd shovel loads directly into 5-ton trucks for the 7-mile haul to the mill. Stoping underground is generally by shrinkage methods modified to allow for rather weak wall rock conditions.

The larger orebodies at the Tulsequah Chief mine are also mined by a modified shrinkage method using diamond drill blast holes for ore breaking. The drilling is done from a raise driven in the orebody with the drill ring breaking to an undercut initially established above the grizzly level.

The **H. B. Mine**, a lead-zinc property near Salmo was brought early in 1953 to the stage where it was ready to go into production at the rate of 1000 tpd. Because of metal market conditions, however, the starting of the operation was deferred until the situation is more favorable.

Rock Drilling

Rock drilling with airleg mounted machines is still giving good performance. Some manufacturers have developed the units to allow feeding air to the leg through the machine, eliminating one hose and consolidating all controls on or near the backhead of the drill.

Chisel type 1½-in. carbide tipped rods are being made locally for use on airleg machines using Atlas Nushank steel. Silver solder brazing of the inserts is done with an oxy-acetylene welding ring. The cost is approximately one half that of manufactured rods and performance equal. At present, 2⅛-in. 4-wing carbide bits are being made for long hole drilling with sectional steel. The bit is forged on one end of the 2-ft piece of Nushank steel with a thread for Gardner-Denver couplings.

In some softer ground, steel bits with ⅞-in. hexagonal rods are used to good advantage with airleg equipment. In drifting and stoping, where bits will give up to 5 ft per run, good performance can be expected.

Limited tests have been carried out using the Holman Dryductor. The application with a stoper would have merit from the standpoint of dust count which is reduced approximately 80 pct of that produced with a standard stoper. However, the dust collection equipment is bulky and would require special conditions for its use.

In stopes the change to bagged 75 pct Dygel from 40 pct Forcite has shown a decrease in powder consumption. This faster, stronger powder gives good results in this application. The 1¼ x 8-in. Dygel is being used in longhole blasting. However, it is not recommended where there is an abundance of water.

Some 3-in. plastic hose has been used for shaft drainage line. In long lengths it is easily installed and gives good service. Elsewhere a 2-in. plastic hose in 100-ft lengths is being used for a water line from surface. The polyethylene hose in 100-ft length and 1-in. size is used for loading deep drill holes.

Roof bolting is being used to a greater extent for holding large slabs on the hanging wall of cut-and-fill and shrinkage stopes. It is felt that the application of rock bolting can be extended. To date the split bolt with wedge in 1 and 1¼-in. size has been used. However, a split anchor type rod using a ¾-in. threaded bolt is to be tested.

In ore transportation a ¾-in. plate slung by chains in the bottom of Granby cars has made the muck slide, increasing the tons hauled per train.

Supplementing the larger Quarrymaster, a new small drilling machine, the Drillmaster, has been introduced. Self-propelled, the unit, complete with compressor, mounts two chain-fed drifters.

Recent Trends in Rock Drilling

by Robert Adamson

Advancements in more economical drilling of large blast holes has played an important part in the increasing emphasis placed on open pit mining of nonferrous as well as ferrous ores during the past year. Development of a large combination percussive and rotary drill in the form of a dual Quarrymaster will be an effective contribution to this increasing trend of raising the ratio of waste to ore. A pilot group of these combination Quarrymaster machines have been given extended field tests under varying conditions, and are now being manufactured. It has been supplemented by the smaller, dual Drillmaster now in the field.

While there has been a distinct swing to heavier equipment in open pit mining, the trend to lighter drilling equipment has expanded in underground practice. These drills have taken over a major por-

tion stope drilling, and drifts rounds up to 8 x 8 ft. An outstanding contribution to this field has been the first integrally constructed jackleg and drill. The effectiveness of this new jackdrill has been increased by the acceptance of the *pear-shaped* shank and improvements in Carset bits. This shank has proven as effective on carbon as on alloy steel.

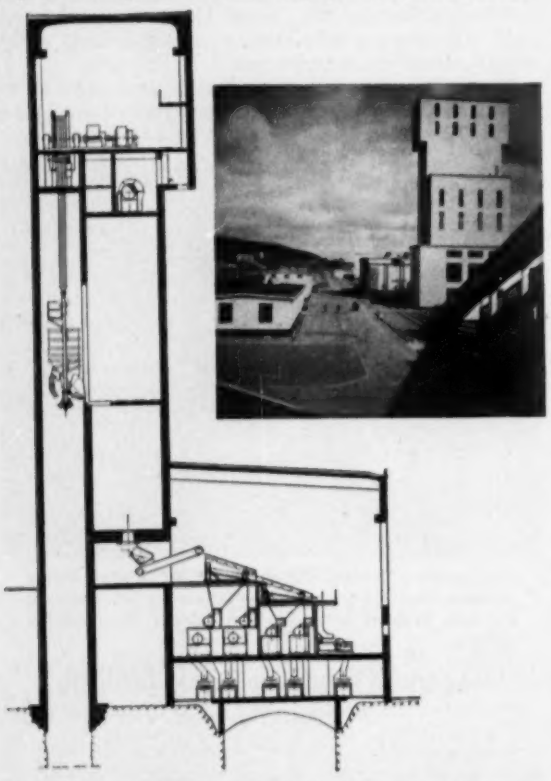
A new alloy hollow drill steel has been developed by the Crucible Steel Co. of America to meet physical specifications written by I-R's metallurgical dept. These specifications stress that the new steel should be uniform following a simple heat treatment. It looks promising in field tests, and will probably be available in quantity in 1954.

Concrete Headframes in Sweden

by J. Fred Johnson

In a trip through the mining areas of Sweden the outstanding features are the concrete headframes at 150 to 240-ft heights, that have supplanted wooden and steel headframes in all major installations.

Adoption of massive reinforced concrete headframes inspired a renewed interest in friction type hoists of the type invented by C. F. Koepe and first installed in 1877. These hoists correspond to the American-grip sheave hoists that never became very popular. Koepe hoists became popular in Sweden only after introduction of the multirope principle, with balancing of cables by tailropes and use of counterweights to reduce the unbalanced load. The growing popularity of these hoists is attested by only 19 being installed from 1938 to 1952 and 31 being on order and in process at the end of 1952.



Section through a reinforced-concrete headframe to be constructed in the Upper Peninsula of Michigan. Note that a Koepe hoisting system will be used. The inset photograph shows an early concrete headframe at Grandesberg, Sweden, for comparison. A conventional hoisting system is in use.

Trends in Dredging

by H. A. Sawin

Bucket ladder dredging for placer gold products never recovered entirely from conditions that developed because of World War II. Primarily today the low price of gold is responsible for the fact that many such dredges are not operating except where they could be adapted to the mining of other products. The major companies in California and Alaska are operating some of their dredges most of which are of large bucket capacities ranging to 18 cu ft each. Other companies especially those with dredges of small bucket capacity closed down early in the war and did not resume operations after. Several dredges in the northwest have been converted from gold production and are used for dredging monazite sands and other rare earths in Idaho. These dredges range in capacity from 4½ to 6-cu ft buckets. Another small dredge built originally for gold mining is used for scheelite production in Montana. Several bucket ladder dredges ranging in size from 6 to 10-cu ft bucket capacity have been dismantled and shipped from properties in California and Montana to Colombia and Brazil for gold dredging.

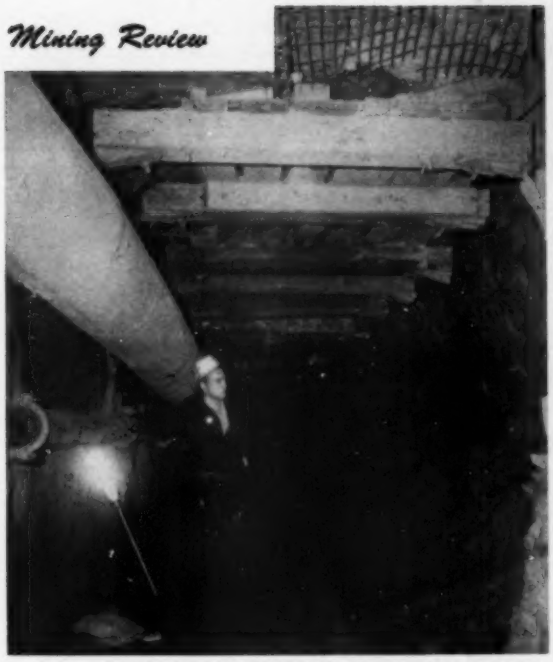
The dredges used in Malaya for mining cassiterite have had a relatively long period of operation under favorable market conditions. Today, however, the price of tin is down from the high levels existing after the war. The lower price may have some bearing on the operation of certain dredges, but no word has been received that any of the dredges would have to suspend operations or operate on a limited period basis.

The use of mineral jigs on dredges has greatly advanced the efficiency of the metal saving equipment. Jigs were once used occasionally on dredges for gold, but in recent years have been adapted and are used almost entirely for dredges mining the rare earths, platinum group metals, cassiterite, and on many gold producers.

While mineral jigs have been used on dredges for some time, Yuba Manufacturing Co. has developed a new application and arrangement which increases the efficiency of jigging systems.

Comparison of Early and Recent Koepe Hoists

	Type	Sheave diam	Ropes		Hoisting Speed	Weights in lb			Motor hp
			No.	Diam		Load	Skip	Balance	
1941 hoist	Two skips in balance	276 in.	1	2¼ in.	3300 fpm	32000	31000		3800
1954 hoist	Skip & Counterbalance	128 in.	4	1⅜ in.	2200 fpm	44000	35000	57000	1150



On the 5200-ft level of the Morning mine, rock bolts are used to support timber and lagging, which in turn support the back. In the foreground, wire mesh is also pinned to the rock with bolts.

Rock Bolting in the Pacific Northwest

by Paul F. Yopes

Four years ago the only pattern rock-bolt installations in the Northwest were in the Belmont mine of the Anaconda Copper Mining Co. at Butte, Mont. Since then over 32 metal mines in this area have used rock bolts experimentally, and bolting is now a standard method of ground support in many of these mines.

Materials

The 1-in. diam, split rod type, mild steel rock bolt is the most widely used. A 4½ or 5-in. thread and a 6-in. long burned slot are fairly standard. Five and 6-ft long bolts are most common. Bearing plates 6 and 8-in. square are commonly used.

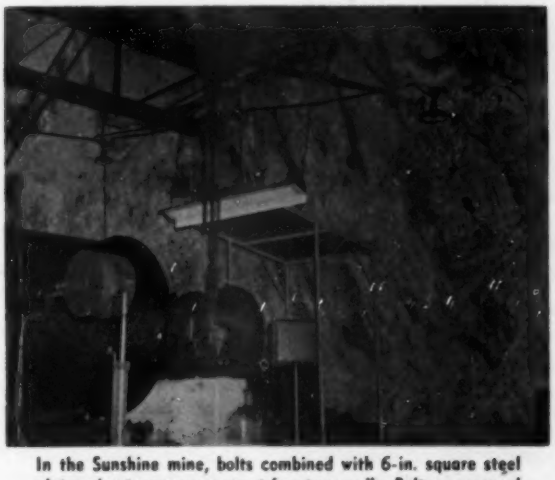
Cast steel angle washers, angle cut lengths of pipe, drilled angle iron, and wooden wedges are used for adjustment when a bolt hole cannot be drilled normal to the rock surface. Short lengths of 1-in. pipe and steel plugs are used to accommodate a hole drilled too deep or not deep enough.

Installation Methods

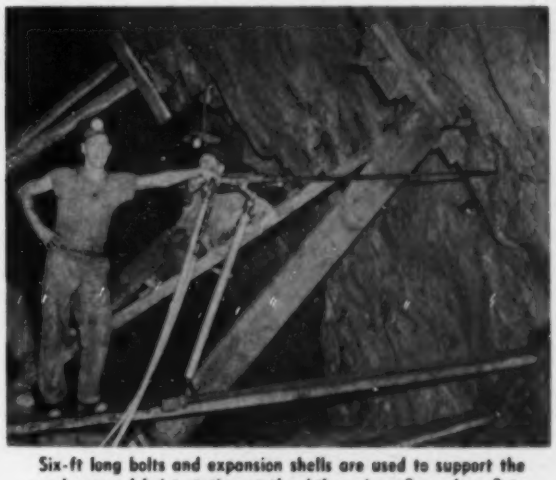
Stopers and airleg mounted air drills are used most frequently for bolt-hole drilling and for anchoring split-rod bolts.

Shafts—Walls are bolted as the shaft is sunk and in advance of the timbering. Placement may be at random, in rings at regular intervals, or in patterns on one or more bad walls. In addition to protecting the shaft crews, the bolts prevent enlargement of the shaft by providing support immediately after the ground is opened. Bolts will protect timbers and facilitate repairs by keeping weight off the sets. Bolting is also used to reinforce the ground before cutting a station or pocket. Overbreak is prevented, timbering is reduced, and potentially dangerous brows are made safe to work under. In shaft repair work, bolting the ground in back of sets or lagging may help keep weight off the timbers and reduce maintenance costs.

Ore Passes, Scram Drifts, and Airways—Plentiful rock bolts, reinforcing iron or mats, chicken wire or other metal lath material, and gunite or reinforced concrete are used in conjunction in opening where irregularities and obstructions are particularly undesirable. Bolts may be placed on as close as 2-ft centers. Reinforcing rods are sometimes welded to the bolt and plate, and 5 and 6-ft long bolts are used. Additional bolts are used to reinforce brows and draw hole throats. Repeated blasting concussion may scale off the gunite shell in scram drifts, making occasional repair work necessary. Airways normally do not need as much protection against wear as orepasses or scram drifts. However, a gunited rock bolt job provides full use of the cross-section, a smooth air-flow surface, and a repair-free permanent support unaffected by mine air or changing air conditions.



In the Sunshine mine, bolts combined with 6-in. square steel plates give temporary support for stope walls. Bolts are spaced in the shrinkage stope to cover a 25-sq ft area. An air-leg setup is commonly used to bolt stope walls.



Six-ft long bolts and expansion shells are used to support the underground hoist station at the Atlas mine. Spaced on 3 to 5-ft centers in rows 4 ft apart, the ¾-in. diam rock bolts were effective in slabby rock.

Annual Review

Developments in Minerals Beneficiation

by Donald W. Scott

Three major points: Tonnages are on the increase and operating troubles become more and more problems of materials handling and control—Revolutionary hydrometallurgical and prometallurgical developments progress beyond pilot plant stage—BUT—Fundamental research lagged.

THE year just ended was the 50th anniversary of that first flight at Kittyhawk, N. C., in 1903. In this 50-year period the aviation industry made startling developments from flight distances of 120 ft—at snail's pace—to speeds of over 1300 mph and flights that circle the globe. And 1953 also was the 50th anniversary of the Utah Copper Co., the Father of our mass production porphyry copper ventures. How do developments in the mining industry stack up with the aviation industry? The mineral industry can be as proud of developments over the past 50 years as the aviation industry. Only for the developments of the mineral industry could aviation and other allied industries advance as they have.

The year 1953 made its contribution to this progress, with the normal number of process and equipment developments and an abnormally high amount of activity in new plant capacity, particularly copper. Tonnages are on the increase and operating troubles are becoming more and more problems in materials handling and control. We're approaching molecular dissemination of ores with hydro and pyro methods coming to the front to take over where flotation leaves off.

The amendment of the Defense Minerals Exploration Administration early in the year to restrict the Government financing program to those minerals only in short supply did not seem to deter activity. This is a good sign but the list of critical minerals still numbers 18.

Research and Education

While our present industry is on sound footing, it must expand if we are to retain our eminence in the world in the next 50-year period. We will need to conserve our known mineral resources by improving our mining and extraction processes and by finding additional deposits by improving our exploration methods. These things will be possible through fundamental research investigations because this is the real foundation for applied research in the recovery of metals from their ores. The industry cannot be proud of its efforts along these lines in 1953.

DONALD W. SCOTT, Chairman of the MBD, is General Manager of Continental Sales & Equipment Co., Hibbing, Minn.

Research activities can be divided into research by Government agencies, and industry sponsored research. Government research continued at a high rate, greatly exceeding industrial research, with the U. S. Bureau of Mines concentrating on the common minerals of which we are in short supply and the Atomic Energy Commission and the Office of Naval Research concentrating on uranium and other minerals of the atomic age. While devoted mainly toward military ends, there is no doubt that this fundamental research will find future applications in the solution of many minerals beneficiation problems.

The USBM started construction of a $665,000 rare and precious metals experiment station in Reno, Nev., to be completed in 1954.

In the field of industrial sponsored research, hydro and pyro methods received emphasis and paid off. Sherritt Gordon's new refinery at Fort Saskatchewan, Alberta, which will produce nickel and cobalt metal powders as well as ammonium sulphate from sulphide flotation concentrates is based on a $2.5 million research program. The plant has been built in anticipation that savings and additional income from the new process over old conventional processes will pay for the research and development costs in a single year's operation at capacity. Research by Anaconda on Greater Butte Project ore has demonstrated the economical and metallurgical advantages of using sponge iron instead of scrap as a precipitant for copper.

Developments in the use of ion exchangers were notable for the following: 1—concentration of metals from (a) mine waters and from (b) heap leaching, leaching in place, or dilute countercurrent decantation washings, 2—separation of mixtures of metals as salts, 3—clarification of electrolytes, 4—regeneration of leach solutions, and 5—direct contact of the ion exchange resin with the pulp for absorption of the metal and then separation of the resin from the pulp for recovery of the metal.

Reports of other investigations were alarmingly meager—a smattering here and there of flotation and grinding investigations, but little else.

There were developments in the field of new tools for research. Radioactive tracers, thanks to the pioneering work being done by Massachusetts Institute

of Technology, are destined to play important roles. The Lapointe picker used at Port Radium and Port Hope consists of a belt scanned by a radioactive detector that activates a ram or gate to divert barren lumps of waste from the run-of-mine uranium ore. The picker is able to reject 40 to 60 pct of the ore in sizes from 1 to 10 in. with a loss of about 4 pct of the uranium values.

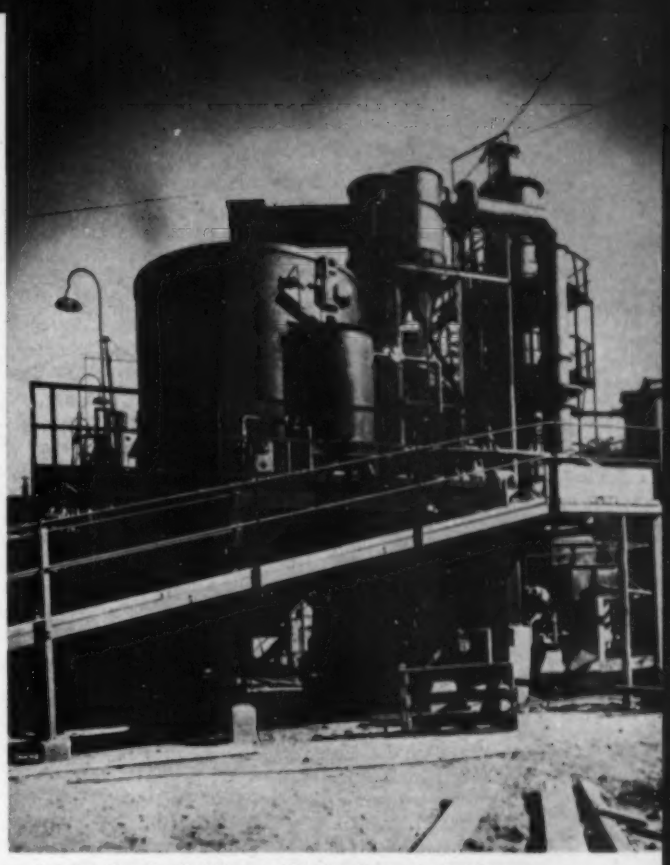
Ultraspeed motion picture cameras now fast enough to make an explosion look like flowing molasses are an important aid in solving problems where unaided observation has proved inadequate. The Sharples Corp. has brought out the Micromerograph for particle size distribution analysis in the sub-sieve range. A button is pressed, and it draws a graph on a chart. *(Were you one to doubt that the Ouija Board would be mechanized some day?)*. The new mass meter developed at MIT applies the principle of Coriolis acceleration to measure liquid or gas flows. In this instrument a torque is developed and measured, which is dependent on the mass flow rate only and independent of fluid, pressure, density, and viscosity. Rapid control analysis has been facilitated by fluorescent X-ray spectrographic techniques. Analysis for a wide variety of elements in a single sample may be made in less than ½ hr. Statistical methods seem to be gaining impetus particularly for cutting down the number of experiments to get an answer that can be depended upon when you get it.

Research efforts appear entirely inadequate if we are to be guided by future demands on the industry as depicted by the Paley report. The industry is falling short of the research necessary for a continuation of our supply of metals and world eminence. Basic research must move ahead of applied research. Several industrial and educational institutes are qualified to do the work but they need the financial support of industry to meet the high cost of fundamental research. That this support has been lacking in a period of excess profits is hard to understand.

In the field of education the dam burst during the year to release a flood of interest in formal training of supervisory and management personnel. The oil companies and many of the mineral companies are now sending key people to such highfallutin places as Harvard to learn how to be managers.

A major change in the methods of accrediting schools of higher learning has been proposed by the Engineers' Council for Professional Development. Engineering education is to be divided into *professional scientific* and *professional general*. The former division will have a curriculum of increased mathematics, physics, and chemistry, and nine engineering sciences, plus four semesters of study of engineering analysis and design for engineering systems. Also proposed is a special designation for institutions substantially above minimum standards with emphasis on faculty eminence. In all probability the standard 4-year course will not provide sufficient time. The objective will be the training of professional engineers, not technicians. This can only be done by a faculty that is truly professional.

Changing to a 5-year course is undoubtedly going to discourage students from entering the profession and this in itself poses another problem. During the year, several mining companies actively participated in a program to acquaint students with the mineral engineering profession. There was a sharp increase in the number of fellowships offered to undergraduate and graduate students in the field of minerals beneficiation. The Minerals Beneficiation Div. of the AIME received a personal contribution to be used in the interest of students enrolled in the profession. A committee was established to work out a suitable student award.



Uranium from South African gold tailing is growing in importance with 15 companies in production or due by 1955. This roaster supplies high strength sulphur dioxide from pyrite for the sulphuric acid plant which produces key reagent for uranium leaching process. This is one of first FluoSolids systems to go into the Rand, and first in world to combine a contact acid plant. Pyrite is available from the ore.

During the year there were few books on the subject of minerals beneficiation. *Hydrometallurgy of Base Metals* by George D. Van Arsdale (McGraw-Hill), 370 pages, contains much operating data in detail, and operators should find it extremely useful.

The proceedings of the Symposium on Mineral Dressing held at the Imperial College of Science and Technology in London Sept. 23 to 25, 1952 were published in *Recent Developments in Mineral Dressing*, Institute of Mining and Metallurgy, London. Of particular interest to small operators is a comprehensive paper on design and construction of small flotation concentrators showing floor plans, elevations, flowsheets, and construction costs in detail.

The Museum of Science and Industry, Chicago, published the *Centennial of Engineering 1852-1952*. In a chapter of this volume, O. C. Ralston reviews the subject of ore beneficiation and hydrometallurgy, presenting a history of the subject with a review of new developments and current practices. If you haven't seen the April 1953 issue of *Fortune* take time to read the article, "New Ways to Metals."

To keep abreast of technical developments, Battelle Memorial Institute abstracts articles appearing in approximately 1000 American and foreign technical journals. These abstracts are now being made available to technologists through the pages of the *Battelle*

Technical Review, which goes to many libraries throughout the world.

Materials Handling

With plants becoming larger and larger there has been a growing realization among engineers designing plants that materials handling is as important as the beneficiation process itself, and that the two must be closely integrated.

Field applications of special conveyor belts provided with raised ribs designed to separate free water from the material being carried while still retaining the material and the moisture content on the belt were proven satisfactory. For effective application, a proper combination of the degree of incline of the conveyor and of the rollers of the supporting idlers must be worked out. This calls for a variable troughing idler, already introduced by at least one manufacturer of conveyor equipment.

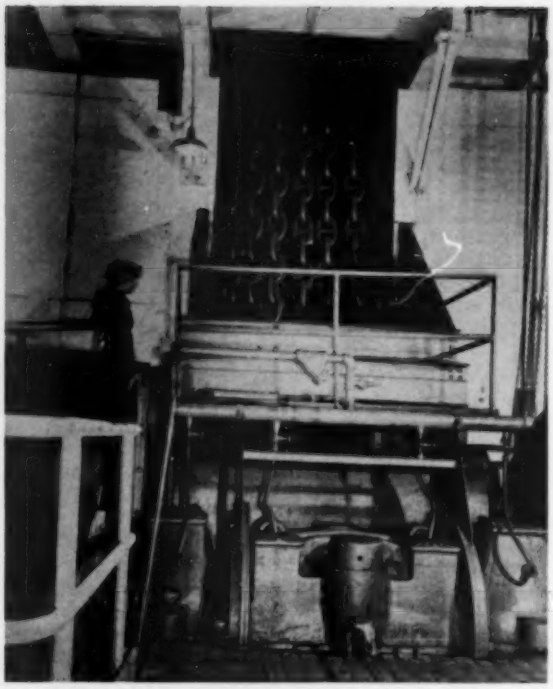
The past year saw closed circuit or industrial television establish itself as an important accessory tool for handling of bulk solids. Complete remote control of a bin filling operation is successfully being done by an operator at a crusher station who has continuous TV observation of the bins at all times.

Hydraulic and electrically energized cushion-type couplings left the gambling stage and became common-place on conveyor drives. These couplings employ electromagnetic control of ac motors for positive speed-torque drive control. A special drive is also being built into ac motors providing an integral unit. The 6000 tph conveying system at Orinoco Mining Co. in Venezuela utilizes a selsyn electrical unit for starting and stopping this complicated conveyor belt layout. Motorized head pulleys for belt conveyors continued to receive publicity during the year. In these units a special motor and speed reducer is mounted inside of the conveyor head pulley. These units have definite advantages for some field applications. They are made in a limited range of sizes, and heat dissipation and repair problems will probably limit their application in the beneficiation field. There seems to be an increased use of heavy-duty disk type return idlers instead of snub pulleys. Major improvements in the internal construction of conveyor belts resulted in more progress in 1953 than in previous years.

Techniques tailor-made to the FluoSolids handling of materials received consideration. It appears that new techniques will be developed bridging existing fluids and solids handling procedures.

Crushing and Grinding

Crushing and grinding equipment continued to follow the trends established a few years back. In crushing, it's still the use of larger sized units. This, of course, would not be feasible if it were not for the general trend of increased tonnage in new plants. Operating costs go down as crusher capacity increases. Most of the new primary crusher installations are gyratories rather than jaws. The manufacturers of these large gyratories are making available some of the features which previously were unique to the smaller sizes. There is a tendency in large plants to increase the number of crushing stages, which is interpreted as recognition of the advantages of smaller reduction ratios. Rolls for intermediate crushing had not received much attention until the recent Hollinger paper was published giving their practice. The rod mill has moved to the fore as the number one machine for reduction in the 1-in. to 8-mesh range. The practice has spread and



This massive crusher installation is underground at International Nickel Co.'s Sudbury operation. Chain links shown weigh 110 lb each.

Broken Hill Consolidated recently installed the first large primary rod mill to be used in Australia. Trends in rod milling are toward increased use of spout feeders, slightly higher mill speeds, end and center peripheral discharge mills for coarse grinding (both wet and dry), lifter profiles without sharp corners, and harder alloy liners which are more wear resistant.

The theory of grinding remained an active subject. The Tennessee Copper ball load test produced some interesting discussions by the experts (*E. & M.J.* for September 1953). Fred Bond's third theory, introduced in 1952 (AIME *Transactions*), continued to receive comment. The Fifth Empire Mining and Metallurgical Congress, Australia, and the Mineral Dressing Symposium, London, actively pursued the subject with many interesting published papers. The Mining Congress arrived at the supposition that the rod mill is more efficient when grinding by impact (at high speeds—80 pct critical and up) and the ball mill is more efficient when grinding by attrition, (at slower speeds down to 55 pct critical). MIT continued to work on two important problems, 1—the accurate determination of physical changes in substances undergoing mechanical size reduction and 2—the determination of the energy changes and the fracture mechanisms accompanying these physical changes, including the role played by travelling pressure waves. E. L. Piret and his associates at the University of Minnesota have also been studying surface energy relationships and fracture and crack propagation. This research, basic to the mechanical size reduction of brittle materials, should shed some light on some of the important unknowns now plaguing the industry.

Canadian milling men are taking a step in the right direction by asking the Dept. of Mines at Ottawa to establish a standard screening procedure so that all mills will evaluate their unit operations of

crushing and grinding on the same basis. With the 80-pct-passing size becoming more generally accepted this attempt at standardization could be helpful in fact finding. There is a feeling by some that metal wear can be more consistently expressed in terms of kw-hr per lb of metal rather than per ton ground. Wet grinding ball and rod wear will average 6 to 7 kw-hr per lb, liner wear about 30 kw-hr per lb, and crusher wear about 35 kw-hr per lb, all including normal throw-away weight.

Allis-Chalmers continued development of the vibrating ball mill. A 15 in. diam x 30-in. mill is seeing plant service in Canada grinding calcite for paper filler. Another mill, 42x42 in., the biggest to date, will be installed in the Southwest for dry grinding cement clinker.

Ball segregation has come in for renewed play. The Hardinge Co. has introduced the Tricone mill with an 8° taper that segregates the balls in the load. Allis-Chalmers advocates Spiral Liners with a 10° angle trailing toward the discharge end. Having the big balls at the feed end and the smaller balls at the discharge end would appear to be an advantage if the feed to the mill were all one size or the size that the smaller balls could not handle. However, when mills are fed ordinary mixed feeds containing coarse and fine particles, the ability of a ball in a mill to select the particle it can handle, somewhat counteracts the advantage of the segregated load. One company has collected some interesting data on this point. The spiral liners are said to increase the flow of material through the mill. This could change the grinding picture and could prove more beneficial than ball segregation. A novel feature in rod mill liner design was suggested by Mac Dermid of Snow Lake, when he proposed and tried using the lift in only the two liners adjacent to the end of the mill. It worked well at Snow Lake simplifying construction and cutting dead weight.

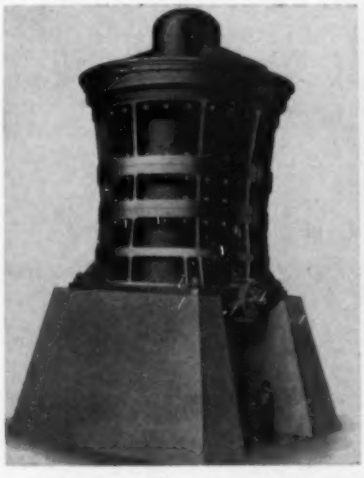
Mill men are generally convinced that power per ton decreased with increased mill diameter, at least to a certain point. Actually little direct data exist for comparison as there are few installations where the same sizes of mills are taking the same feed and grinding to the same mesh. Classification differences complicate the picture further.

The biggest mills to date are those now going in at White Pine, 12 ft 6 in. diam inside of shells, and 13 ft long between feed head liners and inner surfaces of the grates, driven by 1500-hp, 150-rpm synchronous motors. It is now suggested that in high-speed impact mills used in coarse grinding, the capacity varies as the diameter cubed but on slow speed attrition grinding mills, used in fine grinding, the capacity varies as the 2.6 power. If this holds, it could explain some of the past controversies in that operators were invariably comparing mills operating under different conditions.

The number of stages of grinding continues in the controversial column. Fortunately, there are large mills of both single and multiple stage grinding just recently put into operation or scheduled for operation soon, which should either put an end to the argument or muddle it further. Two-stage grinding paid dividends to operators in a Yugoslavian mill, which brings up the point of flexibility in a plant. The tendency towards larger grinding units sometimes results in fewer stages and always in fewer number of mills in a plant. This cuts down the flexibility of the plant and might eliminate the possibility of rearrangement of the flowsheet at a later date to take advantage of new metallurgical innovations. For example, some plants built several years ago with one big ball mill only, were not able to put in rod milling and ball milling when this practice became prevalent without buying new mills and scrapping the old equipment. This important point is sometimes overlooked.

Lake Shore and Wright-Hargreaves have now run their pebble grinding mills for 3 years establishing operating costs. The Neptune mines in Nicaragua are proceeding with the installation of pebble grinding after a successful pilot test. Tennessee Copper is using limestone pebbles to grind limestone at one of its plants. The Johnson's Co. in the asbestos field started up a new installation of 10-ft diam Hardinge mills with air classification.

Installations of Aerofall mills for grinding asbestos are on the increase. At the Daggafontein mine in South Africa a 17-ft diam mill will go into operation this month on gold ore. The anticipated capacity is 1000 tpd from run-of-mine size, (approximately 12



LEFT: The world's largest crusher now being built by Allis-Chalmers for Reserve's taconite project. It's a 60x109-in. gyratory weighing 1½ million lb; with capacity for 3000 tons of taconite ore per hr, it is driven by novel dual drive with 2-500-hp motors. RIGHT: Construction of pit for Reserve's coarse crusher at Babbitt, Minn.

to 14 in.) to 48 mesh. An installation is also planned for Adirondack iron ore. This will be the acid test and will be watched carefully.

Screening and Classification

Results with fine screening were encouraging enough that several installations either have or will be made to give separations at 28 to 35 mesh. These screens use stainless steel cloth, ball tray panels, washing troughs, or higher than normal speeds. Repulping troughs enable the operator to efficiently use dilution to assist the screening process without wearing holes in the screen with water sprays. Mechanical improvements were made on electrically heated screens during the year to apply most of the heat to the screen cloth rather than the frame. Their application is for special jobs.

A screening plant was built on the Mesabi Iron Range making use of the so-called Wobbly screen and feeder. This device is similar to the old live-roll grizzly except that the rolls are elliptical in cross-section. Passing into the realm of commercial utility during the year was the so-called Bergstrom screen in which rubber is vulcanized to a steel plate and the resulting *sandwich* is punched with holes of the desired size. The rubber gives good abrasion resistance and in the punching operation the metal hole is slightly larger than the hole in the rubber which prevents wear to the metal and also prevents blinding.

Cyclones made progress during the year. They seem to be established in the desliming field and are encroaching on the field of conventional rake or spiral classifiers, especially for fine regrind circuits. During the year they were placed in use at Rand Leases Gold Mining Co. in South Africa and the newly expanded mill of the Tungsten Mining Corp. in North Carolina. They are also being tested in other mills throughout the country, including two of the taconite pilot plants on the Mesabi Range. The trend is towards softer rubber linings for better wear and towards lower feed pressures. The choice of machine depends on individual plant peculiarities. There are enough plant installations on test to definitely establish their advantages and disadvantages. The Hydroscillator seems to be making a comeback with an installation in Minnesota during 1953 and two planned for Michigan, all on iron ores.

There would appear to be justification for a standard method of determining classifier or screening efficiency in view of the significance being attributed to better separations in closed circuit grinding. It has been suggested that classification and screening efficiency be determined by plotting the undersize percent passing, and the oversize cumulative percent retained-on, vs particle size. The particle size at the point where the plotted lines cross is the separating size and the percent passing at the crossing point is the efficiency of the separation.

Solids-Fluids Separation

Activity in the field of separating solids from fluids was greater than usual. The pre-coat filter for metallurgical application was introduced at Howe-Sound's Garfield operation. Horizontal pan filters of the dumping type were also introduced with a plant scale installation by St. Joseph Lead in Missouri. Mechanical agitation, as a means of extending the range of the disk type filter, made some progress. Noteworthy installations were made in several of the western copper producing plants. A semicontinuous plate-and-frame press which opens the press, removes and empties the frame, returns a new frame and recloses under pneumatic pressure, all by mechanical power and with a total down time from the end of one cycle to the beginning of the next, of only 1 to 3 min has been piloted, approved and installed on a full plant scale at the Mineral Engineering Co.'s Salt Lake City tungsten refinery. Down time to on stream time has been reduced to 4 to 8 pct.

Polyethylene mona-filament and twisted 3 to 5-ply filaments are being woven into filter fabric. Polyethylene resists acids and alkalies, inorganic salts, and most organic solvents. Its elastic properties make it attractive for cake discharge. In some cases saran, and in others nylon, appear to be the answer for difficult filtering problems, but it is evident that there is a lot more involved than just the size of particle being filtered in selecting the proper filter medium. A paper is scheduled for the AIME Annual Meeting in February outlining a practical approach in the selecting of filter media. Settling and filtering rates can also be improved by a number of special reagents introduced for this purpose.

Flotation

Fundamental research investigations on flotation were alarmingly meager. Hukki and Vartiainen showed that the collecting power of fatty acids increases with unsaturation of the hydrocarbon chain. Gaudin and Cole showed that no oxidation of the double bonds in oleic, linoleic, and linolenic acids takes place during flotation and that the extraordinary utility of these reagents is related to some property of the compounds other than oxidation of their double bonds. Gaudin and Charles measured adsorption of Ca and Na ions by pyrite (using radioactive tracers) and showed that Ca ions are adsorbed more readily than Na at the same pH, helping to explain why pyrite is more readily depressed by lime.

MIT has the following under investigation: (1) equilibrium adsorption studies using tracer-marked flotation reagents as collectors, activators, and depressants, (2) studies of the electric surface charge which results from the unsymmetrical distribution of anions and cations at the mineral-solution interface, (3) studies of the electrical effects resulting from the movement of particles in water, (to obtain information on the composition of the electrical double layer in the solution adjacent to the mineral surface), and (4) investigation of the 3-phase system, mineral-liquid-gas by the adsorption of a volatile collector at all three interfaces.

At the annual meeting of the AIME this month Professors J. Leja and J. H. Schulman, University of Cambridge, England, have a paper on molecular interactions between frothers and collectors at solid-liquid-air interfaces. (See p. 221 this issue.) M. Rey and P. Raffinot, School of Mines and Metallurgy, Paris, France, will present a paper on the theory and practical aspects of flotation of oxidized zinc ores.

USBM RI 4990 provides description of a colorimetric method for determining pine oil in water. Chang et al. (MINING ENGINEERING, Dec. 1953, p. 1282) describe a 50 g pneumatic type flotation setup for mitigating slime and reproducibility problems in laboratory testing.

Studies of the flocculation of slimes, made by the Metallurgy Dept., University of Utah, have indicated that flotation properties and settling and filtering rates can be improved with tailor-made organic compounds. Speaking of tailor-made reagents, attention is called to the article, "Process

Development and Practice of the Potash Division of the Duval Sulphur and Potash Company," November 1953 issue of MINING ENGINEERING. At this property there was a particularly bad clay slime problem. Credit for the success of the process is given in large part to the tailoring of a reagent, Guartec (manufactured by General Mills) to meet the problem. Guartec blinded the structural interstices of the clay mineral prior to addition of the cationic collector reducing the consumption of collector and improving selectivity. During 1953 American Cyanamid Co. placed on the market Aerofloc flocculating reagents, reputed to be effective in increasing the settling and filtration rates of finely divided suspensions where the commonly used flocculants fail. American Cyanamid also marketed Aeromine 2026, a cationic type promoter for silica and other silicate-type minerals.

At the Chemical Market Research Assn. meeting at Pacona Summit, Pa., in September, a symposium dealt with trends of chemicals consumed and produced by the metals industry. R. W. Forsythe of the Dow Chemical Co. discussed the consumption of chemicals in the flotation field. It's big business! Present annual consumption of collectors is 29.9 million lb, of which 32.8 pct is consumed in the U. S. and 16.7 pct in Canada. Annual consumption of frothers is 24.8 million lb, of which 57.6 pct is consumed in the U. S., 12.5 pct in South America, and 11.7 pct in Canada. Lime consumption is 508 million lb per year; soda ash 74 million; copper sulphate 39 million; zinc sulphate 29 million; and sodium cyanide 9¼ million. Mr. Forsythe stated that the market was world-wide in scope and so closely related to the world production of nonferrous metals, that chemical market trends can be predicted quite accurately from metal production trends. From these figures it is understandable why producers of chemicals have their tongues hanging out in anticipation of iron ore flotation plants.

Solution and Precipitation

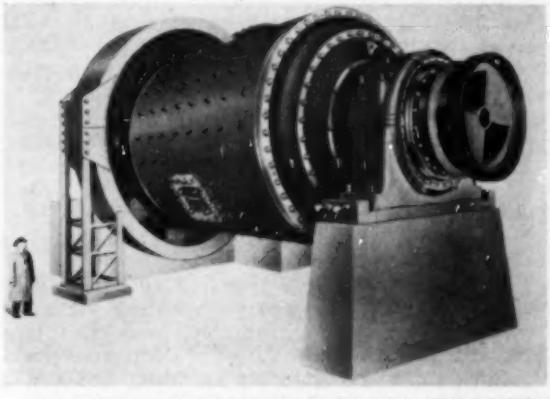
One of the biggest developments taking place in minerals beneficiation is the use of solution techniques. The line between minerals beneficiation and extractive metallurgy is growing very faint. To wit: Quebec Iron & Titanium's process for handling ilmenite ores; International Nickel's matte-flotation for separating copper sulphide particles from nickel sulphide particles; Sherritt Gordon and Chemical Construction Co.'s leaching-reduction techniques for nickel, cobalt, and a whole assortment of metals; AEC's liquid-liquid extraction and ion exchange; and the Dorr Co.'s FluoSolids roasting are going far to create a new Schiaparelli look in metals recovery.

Prof. Frank Forward, University of British Columbia, consultant to Sherritt Gordon, has published much of the Sherritt process by papers given before the Canadian, Australian, and the English metallurgical Engineering Societies. (See MINING ENGINEERING, June 1953.) Professor Forward with V. N. Mackiw will present a paper before the AIME this February entitled "Chemistry of the Ammonia Pressure Leaching Process for Ni, Cu and Co-Sulphide Ores."

The process will undoubtedly have its growing pains—otherwise it would be an exception. One thing is certain, they'll know a lot more about it in 5 years.

The Permutit Co., Rohm & Haas, and others have been doing much work on the application of ion exchangers in the metallurgical industry. Iowa State College has been active in studies producing rare earths by ion-exchange. The AEC, the English and the Australians have also been on the job. It now appears that ion-exchange has its biggest volume future in concentrating dilute solutions of metal salts. In such applications there may be economic advantages when compared with conventional processes such as chemical precipitation, electrolysis or evaporation. Permselective membrane (two types—one that will pass cations and one that will pass anions) ion exchange and continuous ion exchange are being thoroughly explored. An English laboratory has been successful in working on a complex Canadian ore containing gold, copper, zinc, nickel, silver, and iron. The Australians (McNeil, Swinton, and Weiss) have modified the ore dressing technique of jigging as a suggested practical solution to the mechanical problem of large scale countercurrent ion-exchange (paper will be given at February AIME meeting).

Liquid-liquid extraction, coming from the petroleum industry, is based on preferential solubility. Most of the work has been sponsored by the AEC and is in the classified category. The basic principle involves the attraction of one liquid for certain metals in a water solution. If two metals are in a water solution, introduction of a moving stream of nonaqueous liquid will capture one metal by superior dissolving power.



LEFT: The world's largest ball mills, 12 ft 6 in. inside of shells and 13 ft between head liners and grates, built by Mine & Smelter Supply Co. for the White Pine project. Each mill will be driven by a 1500 hp, 150 rpm synchronous motor. RIGHT: Artist's conception of Reserve Mining Co.'s E. W. Davis Works and townsite, near Beaver Bay, Minn.

Applications of FluoSolids roasting are on the increase, the process now having been used successfully for roasting a copper and zinc ore with the electrowinning of both metals. The process is under consideration for iron ores containing varying amounts of sulphur, in the form of pyrite, plus undesirable copper to an extent unacceptable to steel plants. By suitable roasting to solubilize the copper, followed by leaching, the offgrade iron ores can be made usable and the copper can be leached and recovered by cementation. Where careful and selective roasting conditions are required, and there are plenty of these problems in the industry, the method has advantages. A rather wide application of the principle to metallurgy seems assured.

With much help coming from the chemical engineers, minerals beneficiation and metal extraction are no doubt undergoing many important changes. Certainly the two are becoming more closely allied and it won't be long before they will be inseparable. This supports the writer's belief that technical articles dealing with the subjects of minerals beneficiation and extractive metallurgy belong in the same technical publication of the AIME. But let's not start that argument now—as it is, this review stretches from here to eternity.

Agglomeration

Outstanding trends in the field of agglomeration during the year were an increased amount of interest in sintering and nodulizing for the handling of fine iron ore concentrates, and a concerted effort to standardize physical and chemical methods of testing sinter.

The Agglomeration Fellowship at Mellon Institute, sponsored by the American Iron & Steel Institute, continued its service by the development of test methods for sinter quality characteristics. At the AIME meeting this month the following papers will be presented on the subject: "Sinter is What you Make It," by E. H. Rose; "Looking at Sinter Testing," by E. H. Kinelski et al.; and "Solid State Bonding in Iron Ore Pellets," S. R. B. Cooke, et al.

Sintering

A thorough study of quality control of sinter made from flue dust from a Chicago district plant was made public during the year. The industry may finally get away from the descriptive terms of *good* and *bad* sinter, as used in the past. These meant nothing except in terms of the degree of the blast furnace man's unhappiness with the product.

Now that progress is being made toward defining and quantifying the significant properties of sinter, instrument manufacturers are developing continuous recording instruments to evaluate these properties while the sinter is on the machine and something can be done about it. There are already in operation installations where the magnetics content of iron sinter is measured and recorded. One informant on the subject stated that he believed it would not be long before we would have automatic control of the important operating variables, moisture and carbon. This is good news because it indicates a direction of increased tonnage and improved quality.

Operation of the nodulizing plant of Oliver Iron Mining Div., U. S. Steel Corp. at Mount Iron, Minn., was described in a paper by Bennett, Hagen, and Mielke presented at the MBD Divisional meeting in Hibbing last fall. Original difficulties with cold-weather operation and with ring formation in the kiln were overcome so that nodules are now being satisfactorily produced from screened hematite ore and from taconite magnetite concentrates. Indications are that the rotary kiln, 11x350 ft, will produce in excess of 1200 LT of nodules per operating day with a Btu consumption under 2 million and a size consist of product in the order of 45 pct +½ in. material. In general, operation of the kiln was considerably better on taconite concentrates than on natural ore fines, believed due to the greater uniformity of size consist and chemical analysis.

Heretofore, sintering has been regarded as a process capable of handling only the coarser size of ores. The finest material treated commercially has been Copperhill sulphide concentrates which are −100 mesh. The finest oxide material sintered commercially has been about −48 mesh. It has always been possible to blend fine iron ore concentrates with coarser material and sinter the blend at lower capacity. With new developments in fan design, making possible increased fan output and draft, and in bedding procedures, mixtures containing appreciable percentages of −65 mesh hematite flotation concentrates and −200 mesh magnetite concentrates have been handled at sintering rates which, while lower than customary, are in the range of commercial consideration.

There was considerable activity adapting sintering to hardening of balls (unhardened pellets). In this role sintering might be a competitor with shaft furnace hardening procedures. The pelletizing process with shaft furnace hardening of the balls has received more emphasis than sintering and only a year ago seemed to be eclipsing sintering, but recent developments once more interject sintering into the picture for fine-size iron ore concentrates.

The two principal adaptations of the sintering process for this are called by their sponsors, *downdraft* and *updraft*. Actually each process employs a measure of both. A pilot plant continuous sintering machine is being marketed for trials of these processes. The downdraft process corresponds more closely to conventional sintering. The chief object is to secure heat economy by recycling hot gases from beneath the grate to other parts of the machine. This process has been in the pilot plant stage by McKee and Allis-Chalmers at Carrollville, Wis., for about 2 years. Results are reported to be encouraging. Fine magnetite concentrates are easier to handle than specular hematite concentrates. A machine of commercial size is being installed at one of the magnetite taconite processing plants on the Mesabi Range, presumably for comparison of this process with shaft furnace hardening.

The updraft process was developed at the Mines Experiment Station, University of Minnesota. Layers are charged to the machine as follows: hearth layer, thin fuel film, several layers of green pellets. Each layer of pellets is burned substantially through by updraft before the succeeding layer is charged. One iron ore company is proceeding with the design for this process in a plant handling flotation hematite concentrates.

Several patents have appeared during the year on mechanisms for feeding pelletizing shaft furnaces and for discharging pellets from them. During the year the American Ore Reclamation Co., manufacturers of sintering machines and plants, was taken over by the Koppers Co.

The new sintering plant at Benson Mines, which operates on martite or magnetite concentrates, has

U. S. Steel's Oliver Iron Mining Div. Extaca plant near Virginia, Minn., part of $23 million experimental taconite program. The Extaca plant has both a sintering machine and nodulizing kiln.

several unusual design features. Sinter is cooled by a downdraft of air from a separate fan on additional wind boxes, returns are screened, and some are used for hearth layer. Two layers of feed are used on the grates, the bottom one containing less fuel than the top.

Sintering continues as the preferred method for handling screened ores. Two new plants were started during the year. Several more plants are in the design state. One of these is for the new Labrador ores expected the latter part of 1954; another is for the sintering of the major tonnage of ore fines at the head of the lakes before shipment. In Cuba two machines will be installed for the processing of low grade nickel ores of the region. Tennessee Copper is installing an additional machine to double Copperhill sinter production. In Belgium two machines are going in for handling complex nonferrous ores and several machines are reported to be going in at Cerro de Pasco to replace their 42-in. wide machines, sintering first and second-pass lead ores. Operation of the largest sintering machine in the world was described at the AIME meeting in February 1953—12x168 ft, located at Blackwell Zinc Co.

Plant developments at Appleby-Frodingham, England, have highlighted increased interest in sinter for the blast furnace. Blast furnace tests there have led to plans for the sintering of all iron ores used in the plant so that the furnaces will be burdened with 100 pct sinter. Improved furnace performance is attributed in great measure to removal of volatile matter from the carbonate ores on the sintering machine rather than in the furnace shaft. The English work was accompanied by extensive testing in the sintering plant by the British Iron & Steel Research Assn. At least one test of 100 pct sinter is being conducted in an American blast furnace and the preliminary results are said to be favorable.

Plans were announced by two companies to build plants in which sintering will play an important part for the treatment of iron sulphides. International Nickel Co. will build a plant for the treatment of nickel-bearing pyrrhotite to recover nickel, copper, and an iron oxide sinter. Noranda Mines Ltd. is bringing into commercial operation an extended pilot plant study on the recovery of sulphur and sulphur dioxide from pyrite concentrates in which one of the end products is iron oxide sinter. This process is of interest in that by controlling the sintering conditions, about half the sulphur is removed and passed to a Cottrell precipitator, where elemental sulphur is obtained by close temperature control. The sintering is then continued to produce an iron oxide residue low in sulphur.

Two of the three briquetting plants which were producing material for blast furnace feed have discontinued operating.

New Equipment — Mill Design

Every year mill operators and design people have additional pieces of equipment at their command. No doubt some will soon be forgotten and with others we will wonder how we ever got along without them. Raybestos-Manhattan pushed Poly-V transmission belts, reputed to have the advantages of the conventional multi-V-belt without the disadvantage of mismatched belts. Eimco has added mechanical agitation to the metallurgical disk-filter. There is a fluid drive with applications in the metallurgical field, and the Allen-Sherman-Hoff Pump Co. put on the market the new Centriseal pump, a completely rubber lined pump for handling solids but requiring no sealing water. These and other items are scheduled for a symposium, "What's New in Milling Equipment" at the 1954 AIME Annual Meeting.

For dry materials handling several new weighing devices employing strain gauges open up a new field of control tools. These include devices for bin controllers, conveyor weighers, track scales, and many similar items. For wet materials handling, several new pulp density controllers, one employing a radioactive source, are available. One hears that the accuracy is unheard of, one wonders if the maintenance is unheard of. One company in Florida is said to have developed a wet pulp continuous weigher. This is one that the design engineers have always wanted. Closed circuit TV (without Dagmar) offers promise as a useful tool for control. New instruments are available for good control of pyrometallurgical operations including stack gas meters and the other items mentioned in the sintering discussion. USBM IC 7663 describes a densimeter for heavy medium plants.

Important to mill design is dust control and a new filter code just drafted. While an old subject, we have been lax about it. A new steel alloy made in the electric furnace and containing approximately 27 pct chromium, 2½ pct carbon, and 1 pct manganese has been developed by Mason and Cox of Adelaide, Australia. It is reported that the alloy is being used in flotation impellers at Broken Hill.

Plastics are something that the design engineer will be toying with in the very near future. There are innumerable applications in mills especially when used in conjunction with rubber to take advantage of the light weight of plastics and the abrasion resistant properties of rubber. Tanks, launders, ducts, and pipes are some of the applications. The plastic companies have instigated a 2-year research program for evaluating and testing plastic pipe. It is of more than passing interest to note that three steel companies have bought plastic companies outright in the last 2 years.

Commodity Review

URANIUM—While there is little public knowledge about activity in the uranium field, all tidbits of information indicate that it is tremendous. The information available in the literature is sketchy and inaccurate. Much information has been released recently from the confidential category and we have reason to believe that during 1954 someone having the facts will prepare an article appraising the subject. Principal sources of uranium are for the present outside of the U. S., in Canada, Belgian Congo, and the Union of South Africa. Australia is a promising new potential source.

A good deal of activity is centered around the recovery of uranium from gold tailing on the Rand. Some production is already coming from there. The AEC has continued active in prospecting the Florida and western phosphate fields; the research program in connection with the recovery of byproduct uranium from phosphates is continuing; and plans for additional plants are progressing.

Much of the early experimental work on uranium recovery from Rand tailing was carried out at the Western Reefs property. Process details revealed in connection with the opening of a plant at this mine gave the following outline of the uranium recovery process: Residual slimes from gold recovery are treated with a manganese dioxide and sulphuric acid solution. Uranium dissolved by this solution is precipitated and recovered as hydrated oxide. Iron pyrite in slimes from this process is recovered by flotation, the pyrite slurry is roasted to yield sulphur dioxide, and finally a small additional amount of gold is recovered from the calcine. The sulphur dioxide is converted into sulphuric acid for use in the uranium recovery cycle.

Other sources reveal that ion-exchange resins are being used to extract uranium from the leach solution, but few additional details have been released. Some idea of the scale of South African uranium production is given by announcements that 23 properties are scheduled to produce, with estimated capital investment to exceed $150 million.

On the other side of the world, first production of uranium concentrate from Australia's Rum Jungle discovery is expected in early 1954 from Territorial Enterprises Ltd.'s plant now under construction. Both the mining and beneficiation operation at Rum Jungle is by subsidiaries of Consolidated Zinc Corp. Ltd.

Uranium recovery from domestic ores during 1953 was the highest in history, nearly all of it coming from the Colorado Plateau of Colorado, Utah, New Mexico, and Arizona. The Edgemont mining district of South Dakota was one of the newer producing areas in 1953. The milling capacity of the vanadium-uranium properties of the Vanadium Corp. of America in the Colorado Plateau area was increased during the year through the addition of another roaster at its Naturita, Colorado mill. Vanadium Corp. of America continued to be the largest American producer.

Our ninth uranium recovery plant, operated by Anaconda Copper Mining Co. (Blue Water, N. Mex.) went into operation during the third quarter of the year. This new plant treats high lime ores by the caustic leach method, a departure from conventional practice. Construction of a tenth plant for the Navajo Uranium Div. of Kerr-McGee Oil Industries has been started. This will be the first plant in the country designed specifically to treat uranium bearing ores, others having been adapted from plants previously built to handle other ores. The plant will use the Accidulation Process. A substantial quantity of vanadium is expected as a byproduct.

It appears that other uranium concentrating plants will be built during '54. Both the Vanadium Corp. of America, and Utec Exploration Co. have announced plans for new mills. Although all of the present installations in the Colorado Plateau area are leaching plants, considerable attention is being given in the laboratory to research directed to concentration by flotation and ion exchange.

Thickening tailing on the Iron Range. The 130-ft Dorr Torq thickener is at a J&L Steel Co. property, treating 100 tph of −150 mesh material.

Iron Ore

Shipments of iron ore from the Lake Superior region by lake vessel in 1953 amounted to 95,844,444 gross tons, a new all-time record movement of iron ore on the Great Lakes. The goal had been set at 100 million tons and would have been reached if it had not been for a shortage of storage space at lower lake ports.

IRON ORE DEVELOPMENTS AT HEAD OF LAKES—For wash, heavy-media and cyclone ores, the trend has been to carry feed preparation further. All of the plants are now using preparation screens ahead of the Heavy-Media vessels to give a final rewash and thus a cleaner feed. One company has revived the old log washer for scrubbing ahead of the preparation screens whereas two other companies are planning the use of rotary scrubbers. A new drag type of H-M vessel was unsuccessful because of mechanical troubles. All of the new H-M plants have eliminated medium thickeners and washings are pumped directly to magnetic separators. There is a trend toward providing more magnetic separator capacity in the newer plants. Magnetic separators in use are both the drum-type and the newer types of belt separators, although the drum type separators are favored. A development of the past year has been the introduction of Alnico permanent magnet drum-type separators in the secondary magnetic separator position on the theory that in case of power failure they would continue to function and prevent undue media loss.

Contamination of ferrosilicon medium with magnetite, when treating ore that is naturally high in magnetite content, is receiving consideration. At Stripa Gruv AB, Sweden, this problem was solved by tabling the contaminated medium to separate the ferrosilicon from the magnetite. Kaiser's Eagle Mountain H-M plant in California, which is scheduled to start in 1954, will approach this problem by cobbing the feed magnetically to remove the magnetite ahead of the H-M circuit.

There was some critical examination and test work on cyclone plant flow schemes and as a result a number of the older plants are being remodeled to include screening or washing on screens of some of the cyclone products. In some instances, magnetic separators are being mounted in screw-type classifiers to maintain a uniform pulp level in the magnetic separator. The nonmagnetic products drop into the classifier and are dewatered. A problem has been to keep tramp material out of the magnetite medium recovered by the magnetic separators. It has not been definitely determined what is the most desirable size composition of the magnetite medium. Once this has been established it is believed that means will be found to mitigate the tramp problem. Effort is being directed toward trying to bring the capital cost of cyclone concentration plants down to levels that are more competitive with other

processes. Cyclone plants do a superior metallurgical job but in many instances the capital investment may not be justified.

A new jigging plant went into operation during 1953 using Remer jigs (U. S. Patent No. 2,309,275). Two new jig plants are being erected for operation in 1954 to handle the —¼ in. fines from standard H-M plants. These will employ either Remer or Yuba jigs. Yuba jigs will be newcomers to the iron country. Humphreys spirals and Dorr Hydrosizers are still the accepted tools for concentrating classifier overflows. A number of new installations will employ one or both of these devices. Two new abrasion milling installations were made to treat intermediate ores having a soft siliceous matrix.

Taconite

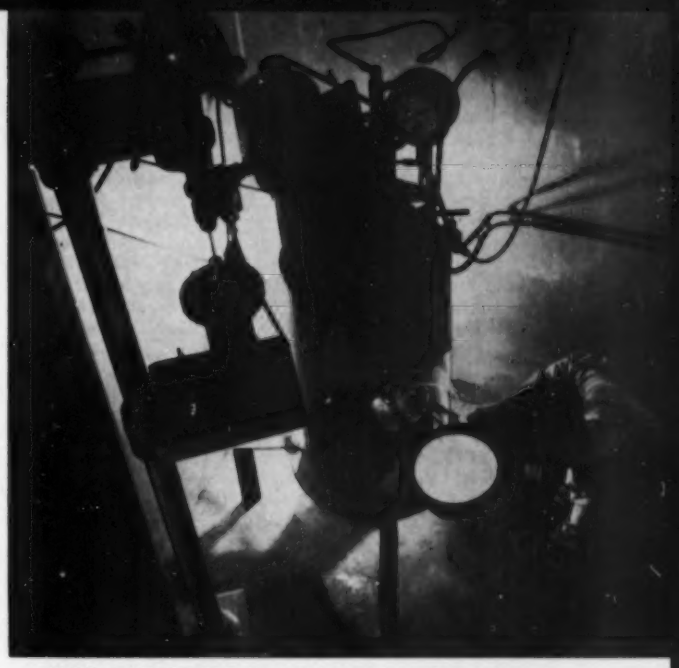
The Pilotac plant of the Oliver Iron Mining Div., U. S. Steel Corp., commenced operation of one of its three units in June and in August the plant was at its designed capacity of 6000 LT of crude taconite per day. Operation of the pilot plant to date has demonstrated that the use of three parallel concentrating sections will facilitate the development of optimum equipment performance and flowsheet. The crushing of the crude taconite in four stages, resulting in a 1-in. top-size rod mill feed is proving satisfactory. In this pilot plant as well as those of Erie Mining Co. at Aurora, and Reserve Mining Co. at Babbitt, the picture is one of testing of different designs of the various components of the ultimate flowsheet. In the grinding circuits, cyclones, the Hydroscillator and screw-type classifiers are being investigated.

The most serious problem faced by the taconite industry is that of agglomeration. Oliver Iron Mining Div. is experimenting with sintering and with rotary kiln nodulizing. Erie Mining is investigating shaft-type pelletizing furnaces, rectangular as well as circular, whereas Reserve is experimenting with four shaft-type pelletizing furnaces with a combined capacity of about 1000 tpd, and is also installing a grate-type pelletizing unit for study.

OLIVER IRON MINING DIV.—No announcement yet of a full-size taconite plant, but Oliver did, however, announce early in the year that a site west of Two Harbors, Minn., had been chosen for a future agglomerating plant for fine iron ore. In its initial operation this plant will handle fines screened from run-of-mine ore. Oliver plans to invest $60 million in the new Two Harbors plant.

ERIE MINING CO.—The Steel Co. of Canada now has a 10 pct interest. In December, Erie announced that it was ready to start the first phase of construction of their $300 million Minnesota taconite development that would be able to produce pellets at the rate of 7½ million tons a year. The beneficiation plant will be located 8 miles northeast of Aurora, Minn., and the harbor and power plant facilities will be at Two Islands, 75 miles northeast of Duluth on Lake Superior. Preliminary excavation for the harbor and stripping of the pit are underway. Approximately 1½ million tons of rock has already been moved at the plant site. The first construction will be on a 5¼ million ton annual capacity plant, which it is estimated will take 3 to 4 years. They are shooting for completion in 1957.

RESERVE MINING CO.—Owned by Republic Steel Corp. and Armco Steel Corp., announced in 1952 that it would go ahead with a large scale taconite processing plant to the tune of $160 million. Its 300,000 ton per year pilot plant at Babbitt, Minn., produced at a consistently good tonnage throughout 1953. But the progress that attracted the most attention was in the construction of Reserve's E. W. Davis Works on the north shore of Lake Superior near Beaver Bay, Minn. The project was named after taconite pioneer, Prof. E. W. Davis, long Director of the Mines Experiment Station, University of Minnesota, in recognition of his great contributions to the industry and the people of Minnesota.



PRESSURE COOKER FOR ORES—The autoclave plays an important role in minerals research. It increases the effectiveness of many hydrometallurgical processes where gases or liquids are reacting with ores.

The Davis Works will be the country's first large taconite processing plant. If all goes according to present plans it will have in 1955 an annual capacity of 2½ million tons of iron ore pellets, made from the taconite mined at Reserve's Babbitt mine and shipped over the 47 mile company railroad to the Davis plant. In 1957 it will have annual capacity of 3¾ million tons. Eventually Reserve hopes to expand this to an ultimate annual 10 million tons.

Aided by unusually good construction weather Reserve during 1953 completed the two breakwaters from shore to islands to form the sides of its big harbor, began the job of facing the harbor, prepared foundations for the buildings of the processing plant, began erecting steel for the first plant buildings, constructed 187 new houses in the town at the lake which is still so new it hasn't been named but which may have a population of 5000 in 1957, extended the new railroad to a point 32 miles from the lake toward Babbitt, and began building another group of houses and another permanent elementary school at Babbitt. All in all, 1953 was a big year for Reserve's big project and definitely shows that Reserve means business.

To the magnetic taconite industry of the U. S. the Sydvaranger operation is of interest, because of the similarity of problems and because of the experience gained through the past few years of operation at Sydvaranger. We call your attention to the October 1953 issue of *Mining World* in which the Sydvaranger story was presented.

While the greatest activity in the Lake Superior district has been directed toward magnetic taconites, nonmagnetic taconites of the area are not being neglected, as evidenced by the developments in Michigan. The initial units of the Humboldt and Republic plants of the Cleveland-Cliffs Iron Co., now under construction, will use all-flotation to recover specular hematite. The Humboldt plant was scheduled to turn its wheels in January 1954. It will use a neutral oleic acid float, which is contrary to the information in some of the earlier releases. There will be no pelletizing or agglomeration plant at the start of operations at Humboldt. However, one will likely be installed later. The Republic plant will include pelletizing.

A good deal of data has been collected on the chemical, mineral and physical properties affecting concentration of the nonmagnetic taconites. Gravity concentration might find some utility for roughing

operations but offers little promise for finishing operations. Flotation in its present state of development holds promise for some special ores but a change in mineral assemblage can disrupt the separation. In favor of reduction followed by magnetic separation are, (1) iron recoveries are expected to be higher in acceptable concentrate grades, (2) a change in mineral composition should not disrupt the process and (3) heat-treated taconites are about twice as easy to grind as untreated taconites and the liberation is improved about one screen size due to better boundary fracturing.

Reduction studies to convert iron bearing minerals to magnetic form were under investigation during the year by several companies. An objective has been to improve the thermal efficiency of the roasting step. FluoSolids roasting, and the Royster process, described in the literature since 1950, continued to receive consideration. In 1953 a new process—Reduction-Oxidation—was described. (Blast Furnace, Coke Oven and Raw Materials Conference, AIME, Apr. 20, 1953). The process involves low temperature gaseous reduction of the iron, controlled reoxidation to gamma hematite, which has the magnetic properties of magnetite, and concentration of the iron magnetically. The exothermic heat of reaction of the oxidation step is transferred directly to the gaseous reduction step eliminating the need for fuel. Continuous pilot tests at Battelle Memorial Institute with a 2-ft shaft furnace using feed rates up to 600 lb per hr indicate that the process has possible commercial applicability.

The present high cost of reducing agents on the Lake Superior iron ranges will undoubtedly delay developments. Should they become available at a reasonable cost it would be a boon to the area. It is interesting to note that during the year request was again made for permits to bring natural gas in from the Dakotas or Montana. The new refinery at Wrenshall, Minn., processing crudes from Canada, got up to full capacity production during the year.

IRON ORE DEVELOPMENTS IN OTHER AREAS—At Benson Mines, the martite plant with spirals is giving good results and will be expanded. Flotation is being considered. Republic Steel at its Port Henry concentrator has installed additional equipment to recover nonmagnetic iron ore as well as magnetic ore and thereby increase the life of Republic's Fisher Hill mine. At the Grace mine of Bethlehem Steel Corp. in Morgantown, Pa., work is under way to bring a large deposit of magnetic iron ore into production.

At the Ohio mine in Michigan, jigs are being added to the flow scheme to fill the gap between the previously installed H-M unit and Humphreys spirals. In Alabama, Woodward Iron started up its 400-tph H-M plant. Woodward has begun mining in an area where two seams of good ore are separated by a middle-man of sandrock. The plant will enable them to mine the whole business. USBM RI 4988 describes recent investigations of Alabama red iron ores.

While on the subject of iron it is of passing interest to note that during the year Republic Steel announced plans to build a powdered iron plant. There has been a lot of conjecture by a lot of people that it should be possible to make pure iron by means other than the conventional blast furnace and open hearth.

MANGANESE—Our domestic deposits of manganese are large enough, but they are all low grade and tough to crack while staying within economic limits. While diligent effort continued during the year, there is nothing startling to report. Beneficiation of manganese ores from Aroostook County, Maine, will require either pyro or hydrometallurgical treatment because of the intimate association of the manganese with iron and siliceous minerals. Extensive work done at the Boulder City, Nevada Station of the USBM has demonstrated that our domestic manganese ores such as those of Artillery Peak, Ariz., in which the diluent is opaline silica, respond to caustic leaching. Flotation concentrates can be upgraded from about 31 to 36 pct manganese by removal of about two thirds of the opaline silica. Spent leach liquors can be regenerated with lime, which precipitates calcium silicate and regenerates sodium hydroxide. If the process can be proven to be practicable on the Artillery Peak ores it is likely that it will work on other deposits in the country of a similar nature, but it won't be cheap.

After 2 years of construction, Pioche Manganese Co. put into operation at Henderson, Nev., an electric furnace to produce ferromanganese from manganese nodules. The manganese comes from its 2500 tpd manganese-lead-zinc flotation mill at Castletown, Nev. A production of around 1500 tons of ferromanganese per month is planned.

A 1000 tpd flotation plant was tried out in Henderson, Nev., by Manganese Inc. but kiln trouble early in 1953 and a plant fire in the second quarter prevented any prolonged operation. This flotation mill is expected to be back in operation in the first quarter of 1954. In New Mexico two H-M plants are being installed for upgrading of manganese ores for sale to the government buying station at Deming.

A $3 million manganese recovery plant, financed by the Government, was under construction during the year at Batesville, Ark. Because of default the Government cancelled the contract late in the year.

Manganese Chemical Corp. erected a plant at Riverton, Minn., to test the ammonium carbonate process. Magnetite concentrates will be a byproduct. The plant was started up late in the year.

Mangaslag Inc. began late in the year to operate a pilot plant at Coxton, Pa., to recover ferromanganese from open hearth steel furnace slag. While this subject has held a lot of interest for several years, this will be the first plant to recover manganese from slags.

COPPER—Copper activity during the year was strong. Anaconda is now treating partially oxidized ore from the Greater Butte project by a leach-precipitation-flotation technique. The ore is crushed, leached in scouring mills at pH2, then classified into sand and slime products. Sands are ground and floated in a conventional basic flotation circuit. Sponge iron is added to the slime pulp, precipitating the dissolved copper from solution and the acid pulp is then floated with Minerec A as the collector. Coarse sponge iron is recovered from the flotation tailing and returned to the precipitation tank. The sponge iron is produced from pyrite flotation concentrates by reduction of iron calcine at 1850°F with coke made from slack coal. It is a −35 mesh product containing about 50 pct metallic iron.

The first of the new big copper mines to be opened since World War II began production at Yerington, Nev., (Anaconda Copper Co.) in the latter part of 1953. The orebody contains about 35 million tons of copper oxide ore having a grade of 1 pct copper. Underneath lies a sulphide orebody containing an estimated 15 million tons. The plant to treat the oxide ore employs sulphuric acid leaching and cementation. To

HEAVY-MEDIA

New in 1953 in Minnesota: Virginia Mine, Skubic Bros., 175 LT per hr; Hawkins Extension, Cleveland-Cliffs Iron Co., 200 LT per hr; West Hill mine, Pickands, Mather & Co., 200 LT per hr; and Biwabic mine, Pickands, Mather & Co., 175 LT per hr.

In other fields the count is: 26 plants under construction
175 now installed
57 cleaning coal—38 for iron ore—28 on base metal sulphides—52 treating other minerals.

Cyclone plants in Minnesota: Harrison plant, Butler Bros., 125 LT per hr; Hawkins plant, Cleveland-Cliffs Iron Co., 160 LT per hr; Hill Annex plant, Jones & Laughlin Steel Corp., 125 LT per hr; Hill Trumbull plant, Mesabi Cliffs Mining Co., 160 LT per hr; and Virginia plant, Zontelli Bros., 80 LT per hr—and 3 more for 1954—M. H. Hanna Co., Maroco mine; Pickands, Mather & Co., West Hill, and Mahnomen mines.

In other fields: Two scheduled for base metal sulphides.

assure a reliable source of sulphur, Anaconda acquired the Leviathan sulphur mine in Alpine County, California. Sulphuric acid will be produced by FluoSolids roasting of the sulphur ore and conversion of the resulting SO_2 gas to acid. Production will be at the rate of 11,000 tons of ore per day and ultimately add 5½ million lb of copper per month to our production. Full production is scheduled for 1954.

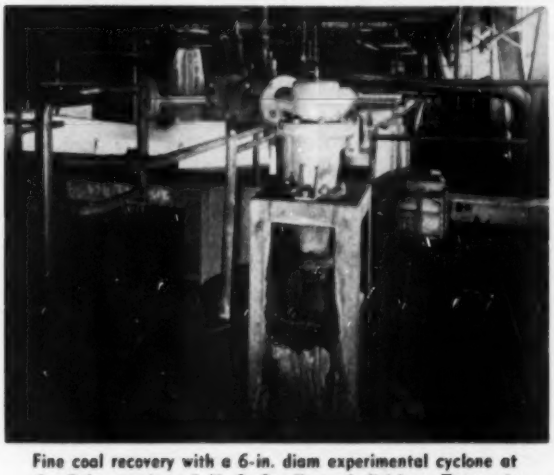
The Ray Mines Div. of Kennecott Copper Corp. operated throughout the year with its new concentrating plant. Outstanding features of this plant are its elaborate dust control system and the extensive use of Corrulux-corrugated, translucent plastic panels for exterior sheeting, replacing windows and permitting diffused natural lighting without the heat normally admitted through glass. Kennecott has plans to develop a new open pit copper mine in Nevada known as the Veteran. Although this deposit was mined by underground methods, it has not produced since 1914. The Deep Ruth mine of Kennecott in this same area, for which it was necessary to move the entire town to operate new shafts, will be in full operation in 1954.

At the Arthur and Magna concentrators of the Utah Copper Div. of Kennecott, the flotation cells were replaced by larger sized cells, to increase capacity and to improve recovery of copper and molybdenum. Tennessee Copper Co. during the past year reduced its smelting cost by removing talc from the final copper concentrate through an additional flotation step in which the talc was depressed by the use of cold caustic starch and SO_2, the latter coming from the waste liquors of the sulphuric acid plant.

The 7500-tpd Silver Bell Mill of AS&R at Silver Bell, Ariz., near Tucson, is nearing completion. Initial operation is expected in March 1954. The deposit is a low grade porphyry copper. Concentration will be by conventional flotation methods consisting of regrinding of rougher concentrates before cleaning and scavenger flotation of the first cleaner tailing. Although crushing is set up for open circuit, it can be easily converted to closed circuit crushing in the tertiary stage. In the primary grinding circuit the ball mills will be close circuited with conventional screw-type classifiers. The ball mills in the concentrate regrind circuit will be closed circuited with cyclones.

The Bisbee mill of Phelps Dodge is nearing completion, but probably will not go into operation until late 1954 pending stripping of the new pit and preparation for mining ore. Equipment and flow sheet are similar to the Morenci mill in many respects.

The Castle Dome mill of Miami Copper Co. was to cease operations on December 4 and equipment and buildings were to be moved to the new Copper Cities location where operations are expected to start in late summer of '54. The Copper Cities property is estimated to have a reserve of 33 million tons.



Fine coal recovery with a 6-in. diam experimental cyclone at the Robena mine of U. S. Steel's coal division. Test unit handles 100 gpm of hydraulic classifier overflow, recovering fine coal and eliminating high ash slimes.

Hinging on the announcement that DMPA would buy copper produced under contract up to 5½ million lbs at 29¢ a lb until June 1956, the Copper Creek Consolidated Mining Co. reported plans to leach copper in place from its underground workings at the idle Old Reliable mine, 30 miles southeast of Hayden, Ariz. The Riviera Mining Co., Winkelman, Ariz., acquired the Christmas copper mine and built a small mill (100 tpd) for treating the ore. The concentrates are shipped to the Custom Smelter of AS&R at El Paso.

The Bagdad Copper Corp. announced plans to expand mining and to modify milling to include a roasting, leaching and electrolytic plant. If this materializes it will be the first copper refinery there.

San Manuel project is well under way. Many of the houses in the townsite have been completed and ground is being broken for the mill and surface plant. Plans call for an ultimate capacity of 30,000 tons of ore per day with an annual production of about 140 million lb of copper and about 3000 tons of molybdenum concentrates and some precious metals. Commencement of production is scheduled for late 1956. In the process for the separation of the molybdenum from the copper it is rumored that conventional heating will not be used, as practiced by Utah Copper, the steaming as practiced by Chino or the polysulphide method used by Morenci.

In September, AIME members were given an opportunity to witness developments of the White Pine Copper Co. when this company was host to the Upper Peninsula Section. The concentrator will have a daily capacity of 15,000 tons. Milling will follow the Morenci procedure and mining will be similar to the Tennessee Coal & Iron procedure. The construction of the crushing plant and concentrator continued according to schedule and by the end of the year the structures were substantially completed. The installatiton of the crushers, ball mills, and classifiers has been started and considerable progress has been made in the preparation of the tailing disposal area. The mill is scheduled to start during the latter part of 1954.

Chemical Construction Corp. has designed the first scrap-copper plant to use its process for Whittaker Cable Co. at Kansas City. Scheduled for production in 1954, the copper powder product will be rolled into rod for wire drawing.

In the Union of South Africa the O'okiep Copper Co. Ltd. advanced well with construction work to increase the capacity of the mill by 50 pct. Design work was under way for two new mills in Northern Rhodesia. One is the Bancroft of Anglo-American, a 5000 tpd flotation concentrator; the other is the Chibiluma mill of Selection Trust, a 1600 tpd flotation mill to treat a copper-cobalt ore. AS&R through its subsidiary, Southern Peru Copper Corp., continued with engineering and cost studies to develop the Toquepala deposit with an indicated ore reserve of 400 million tons of 1 pct copper. Plans call for mining 22,000 tons of ore per day.

ZINC-LEAD—The shift from shortage to oversupply of zinc during the year was reflected in the sharp drop in zinc price, causing drastic cutbacks in mill production, and a general unhealthy situation in which a great many of the small producers succumbed entirely. About 20 small producers in British Columbia, all of the producers in New Mexico, and Colorado and many of the producers in the Missouri-Kansas-Oklahoma tri-state district and in Utah and Idaho ceased operation.

In Canada, however, several new and large producers which completed their first full year of operation—Barvue Mines in Quebec with its 5000 tpd mill, and the Mundamar Metals in Nova Scotia operating a 500 tpd mill, together with some expansion by the Consolidated Mining & Smelting Co. at Trail, British Columbia—served to maintain Canadian estimated production equal to, or in excess of that in 1952. A new fuming plant by Hudson Bay Mining & Smelting

Co. also added to the year's production. An important new development was the starting of construction of a 200 tpd lead-zinc mill by Keymet Mines Ltd. at Bathhurst, New Brunswick. It is scheduled to be the first mill in operation in this recently discovered and much heralded lead-zinc district. Consolidated Zinc Corp. of Canada, a subsidiary of Consolidated Zinc Corp. Ltd. of London, acquired an interest in New Insco-Mines Ltd. and will explore property in the Lake Dufault district of Quebec.

Pennaroya's operation on the flotation of oxidized zinc ores on the Island of Corsica is said to be proceeding successfully. Reputedly, the procedure uses sodium sulphide for sulphidizing the zinc oxides followed by flotation with amines. Our information on this development was scanty. In view of the association of oxide values with U. S. sulphide ores it will bear watching.

Still another development of significant interest is the successful operation of a commercial installation in Japan for FluoSolids roasting of a copper-zinc ore. Previously this ore was smelted for the copper content, about 9 pct; and the zinc content, about 13 pct, went into the slag and was lost. Now, by a sulphating roast of the concentrate, the copper and the zinc are converted into sulphates with 95 pct solubilizing of these constituents. The leach solution is precipitated electrically, first the copper and then the zinc. This is a good illustration of creating a zinc reserve by an improvement in metallurgy.

In the U.S. the mine and mill shutdowns no doubt resulted in a big reduction in zinc production for 1953. However, some activity was still in evidence. New Jersey Zinc announced plans to develop the lead-free sulphide ore in the vicinity of Jefferson City, Tenn. The Keystone mill of AS&R, 200 tpd lead-zinc, near Crested Butte, Colo., was completed in early November. This mill will probably not be placed into operation until there is some improvement in the prices of lead and zinc. AS&R's 100 tpd Van Stone mill near Northport, Wash., completed its first year of operation. The ore contains about 4 pct zinc and ½ pct lead and is concentrated by conventional differential flotation at a rate of 1000 tpd. Eagle-Picher is constructing a new roasting and sintering and sulphuric acid plant at Galena, Kans., and Pend Oreille Mines & Metals Co., Metaline Falls, Wash., while curtailing actual production, continued construction of the third 800 tpd unit.

Although the severe cutbacks and shutdowns in zinc in the U. S. and western Canada also affected lead, the outlook and price for lead has continued throughout the year to be better than for zinc. Especially to be noted is the $12 million smelter renovation and expansion at the COMINCO smelter in Canada which should be completed early in 1954, and the new smelter under construction at Kellogg, Idaho, by the Bunker Hill & Sullivan Mining & Concentrating Co. St. Joseph Lead Co. started operation of the Indian Creek unit (2000 tpd) at Potosi, Mo., in the fourth quarter of 1953.

Gold and silver as a byproduct has helped many a copper, lead, and zinc producer as an added source of revenue. For a comprehensive compilation of gold and silver producers and production figures, we refer you to the July 4, 1953 issue of *Skillings' Mining Review*.

TUNGSTEN—Producers of tungsten organized during the year to form the Tungsten Institute with headquarters in Washington, D. C.

Gravity concentration continued the favorite method for the recovery of tungsten minerals, but flotation is being used in some places and considerable experimentation was underway during the year to improve the effectiveness of flotation procedures. In Arizona a 400 tpd copper-tungsten mill scheduled for completion in March 1954 is being built for the Banner Mining Co. near Sahuarita. Chalcopyrite will be recovered by flotation and scheelite by gravity concentration. The Tungsten Mining Corp. at Tungsten, N. C., in an expansion which began in 1952, increased tungsten mill capacity from 300 to 600 tpd. Climax Molybdenum Corp. at Climax, Colo., completed Unit No. 3, 5000 tpd, in the first quarter of 1953 and plant Unit No. 4, 5000 tpd, will start up in the first quarter of 1954. The ore contains molybdenum, tungsten, and tin. The Black Rock Mining Co. at its Lincoln mine in Tempiute, Nev., rebuilt its concentrator during 1953. Black Rock changed from all-flotation to flotation of deliterious sulphides followed by sand-slime separation of tailing. The sands are tabled for production of 60 pct tungsten concentrate. Slimes are floated for production of low grade tungsten concentrate. Minerals Engineering Co., Glen, Mont., completed and started operating a 300 tpd flotation plant during the fourth quarter.

The Salt Lake Tungsten Co. built and put into operation late in 1953 a tungsten refinery. This plant will treat low grade concentrates by a pressure leach with sodium carbonate to produce soluble sodium tungstate. In a subsequent operation, the solubilized tungsten is precipitated with lime as calcium tungstate of a grade accepted for Government purchase. The expected production is 200,000 lb of WO_3 per month. Wah Chang Corp. fired two new furnaces of a total of 6 at its Glen Cove, L. I., refinery. Full capacity will be employed only in the event of war.

The Government completed a contract between King Island Sheelite Ltd. to obtain tungsten concentrates from Tiny King Island which is located in Bass Strait between Melbourne, Australia, and Tasmania.

TITANIUM—Titanium is moving ahead rapidly from the physical metallurgy viewpoint and plants are being enlarged or new ones are being built for making sponge. However, there is little new on titanium ore beneficiation. Titanium Metals Corp. (owned jointly by National Lead and Allegheny Ludlum Steel Corp.) expanded its plant facilities at Henderson, Nev. This plant uses rutile obtained from Australia because it is more convenient and just as economical to import this high grade TiO_2 than to ship ilmenite from the East and purify it. The Sorel plant of Kennecott did not reach full capacity during the year. It obtains its ilmenite from Allard Lake and removes the iron by electric furnace smelting to yield a titanium slag sold as a raw material for pigment plants.

Dupont announced plans to produce ilmenite from a Florida sands deposit near Lawtey, Fla. The plant will be built and operated for Dupont by the Humphreys Gold Corp. and will be patterned after the Trail Ridge plant, Fla., which Humphreys already operates for Dupont. It will be located 17 miles north of the present Trail Ridge plant. Production from this plant will help Dupont meet the increasing demand for titanium metals and titanium pigments.

NICKEL-COBALT-CHROMIUM — Several new and widely different processes for the recovery of nickel from sulphide ore or siliceous and iron laterite ores were put into production or actively studied in 1953.

A smelting plant near Riddle, Ore., is under construction for the Hanna Nickel Smelting Co. to treat low grade siliceous nickel ores. Four electric melting furnaces for the production of ferronickel are expected to be in operation by the end of 1954 with a production goal of around 100 million lb annually.

In Canada the Fort Saskatchewan refinery of Sherritt Gordon Mines Ltd. is being completed to make separate nickel and cobalt products from sulphide concentrates of Cu-Co-Ni by a high pressure ammonia leach developed by the company. Pregnant solutions are treated to selectively precipitate the three metals. This refinery, which is expected to be in operation soon, is designed for a production of 8500 tons of nickel and 150 tons of cobalt annually.

Operating problems have been encountered at the Howe Sound plant at Garfield. Corrosion and erosion have given trouble. Changes were indicated and they are being made. The plant is producing specification cobalt but not at designed capacity. Costs have been higher than the low level initially indicated but they will probably drop when operating problems are worked out. National Lead's plant at Fredericktown,

Mo., to make copper, nickel, and cobalt metal products is in the starting-up stage now.

The renovated Nicaro plant in Cuba, which treats nickel serpentine laterites by an ammonia leach of roasted ore, continued to improve its operation and recovery. A production rate approaching 30 million lb annually was being attained at the end of the year. Freeport Sulphur Co. in cooperation with Chemico has built a pilot plant for the high iron-laterites to try out a pressure sulphuric acid leaching process with controlled precipitation of nickel and cobalt by hydrogen under pressure. Freeport visualizes a production by 1955 of 30 million lb of nickel annually from Freeport's Moa Bay deposit, which carries about 1.35 pct nickel and 0.14 pct cobalt and is estimated to contain 500,000 tons of nickel metal and 50,000 tons of cobalt. Bethlehem Steel Co., which also holds a reserve of nickel-bearing laterite in Cuba, has developed a nitric acid process which Bethlehem believes to be suitable for nickel extraction from the high-iron laterite ores.

International Nickel Co. announced that it would produce nickel, and byproduct iron oxide and sulphur from Inco's nickel bearing pyrrhotite at Copper Cliff. The recovery of iron as a high quality (65 pct iron) byproduct is an advancement in nickel extractive metallurgy, since in conventional processes the iron content of the ore is rejected in a slag or tailing. The process will make it possible to treat ores that were otherwise considered uneconomical for the recovery of nickel alone. A 5-year contract signed with the Government calls for the delivery of 120 million lb of defense vital nickel without diversion of regular supplies.

The chromium market continued strong and all of the producers in 1952 continued to produce in 1953. In late 1953 the American Chrome Co. started up its 1000 tpd gravity concentration plant at Nye, Mont.

Vanadium Corp. of America announced a $3½ million addition to its Graham, W. Va., plant for the purpose of producing a very-low carbon ferrochromium. The special ferrochromium is reputed to permit the production of extremely low carbon content stainless steels without resorting to special modifications of furnace and smelting practices, generally necessary with usual low carbon ferrochrome alloys because of their high silica content. Vanadium Corp. also began construction of a concentrating mill for chromium ore at its Southern Rhodesian properties.

ALUMINUM AND MAGNESIUM—With the completion of the eighth and final potline at the Chalmette, La., plant of Kaiser Aluminum & Chemical Corp., the New Orleans area has the largest aluminum reduction plant in the U. S. and the second largest in the world. The expansion at Chalmette has doubled its capacity from 100,000 tons to 200,000 tons of aluminum annually.

At the newly completed Reynolds Metals Co.'s complex plant at Corpus Christi, bauxite ore will be brought in by deep water transportation from the mines and processed from ore to pig metal. A special feature of this reduction plant is the size of the electrolytic cells or pots, which are designed for 105,000 amp; this is two or three times conventional usage. Reynolds rates each of its two pot lines at 80 million lb per year; latest plants of both Alcoa and Kaiser rate their pot lines at 42 to 50 million lb each. Reynolds is also putting up a 55,000-ton reduction plant.

Plans were announced by the Anaconda Aluminum Co. (owned 95 pct by Anaconda Copper Mining Co.) to build a $45 million aluminum reduction plant with a rated capacity of 55,000 tons per year at Columbia Falls, Mont. Production is anticipated in 1954.

Kennecott announced plans to explore and develop bauxite ore in the British and Dutch Guianas.

In the research field the USBM studied the recovery of aluminum from anorthosite at Laramie, Wyo.

In 1951 the Government reactivated six of its wartime magnesium plants. Five of these plants, an electrolytic plant at Painesville, Ohio, and four ferrosilicon process plants at Canaan, Conn.; Wingdale, N. Y.; Manteca, Calif.; and Spokane, Wash.; were either closed or recommended for closure by the end of 1953. Only the Government-owned sea-water plant at Velasco, Texas, was scheduled to remain in operation. This plant, now operated for the Government by the Dow Chemical Co., together with Dow's own sea-water plant at Freeport, Texas, constitutes the present magnesium production facilities of the country. Magnesium production, up from 40,900 in 1951 to 105,800 in 1952, will now be on its way down again. It is to be concluded that there has been a considerable easing of the magnesium situation in the last 12 months.

PHOSPHATES AND POTASH—The American Agricultural Chemical Co. installed a Green belt-type concentrator at its South Pierce washer near Brewster, Fla. This concentrator was developed several years ago by the Minerals Separation laboratory for separating the intermediate sizes of phosphate (14 to 35 mesh). American Cyanamid Co. installed a new bowl rake classifier which will permit doubling the feed capacity to the flotation section of the Sidney plant. A coarse flotation operation has been developed and will replace the belt concentrator in the Sidney plant. The 48-in. wet cyclone for primary desliming continued to operate throughout the year with satisfactory results from the standpoint of both metallurgy and maintenance cost. The 700-ft diam thickener with 300-ft rake mechanism also continued to operate.

Big news was Armour & Co.'s entering the phosphate field as a producer. During the year construction was started on a phosphate plant designed for Armour by the Attapulgus Mineral & Chemical Co. It is scheduled for completion in late '54. Attapulgus claims a new beneficiation process for phosphate, but we have no definite information in regard to it.

Coronet Phosphate Co. sold its holdings to the Smith-Douglass Co. A drying plant was moved from Coronet near Plant City to the Tenoroc mine near Lakeland. The spiral section of the Nordlyn plant of International Minerals & Chemical Co. was doubled permitting additional feed tonnage to the plant and improved metallurgy. The Bonnie Chemical plant of IMC commenced operation during the year. Virginia Carolina Chemical's new wet rock storage facilities at Nichols, Fla., were nearing completion at the end of the year. Live storage of 200,000 tons of wet rock and total storage of 400,000 tons will be provided, and the use of a double stacker will eliminate the need for bulldozers.

International Minerals & Chemicals Corp. is still not saying much about the LeBaron-Lawver process for concentrating phosphate and potash ores which it announced early in the year. From grapevine talk we surmise that it is a dry beneficiation process with the finely ground ore passed between electrodes. IMC has a $1 million pilot plant operating continuously on phosphate in Florida and the same size unit just starting up in Carlsbad, N. Mex., on potash.

The new potash mills of Southwest Potash and of Duval near Carlsbad, N. Mex., reached full production during 1953. Of interest in the Duval process is the close temperature control practiced to precipitate the KCl with optimum crystal size, and the *straight jacketing* of a troublesome clay slime with a tailor-made reagent.

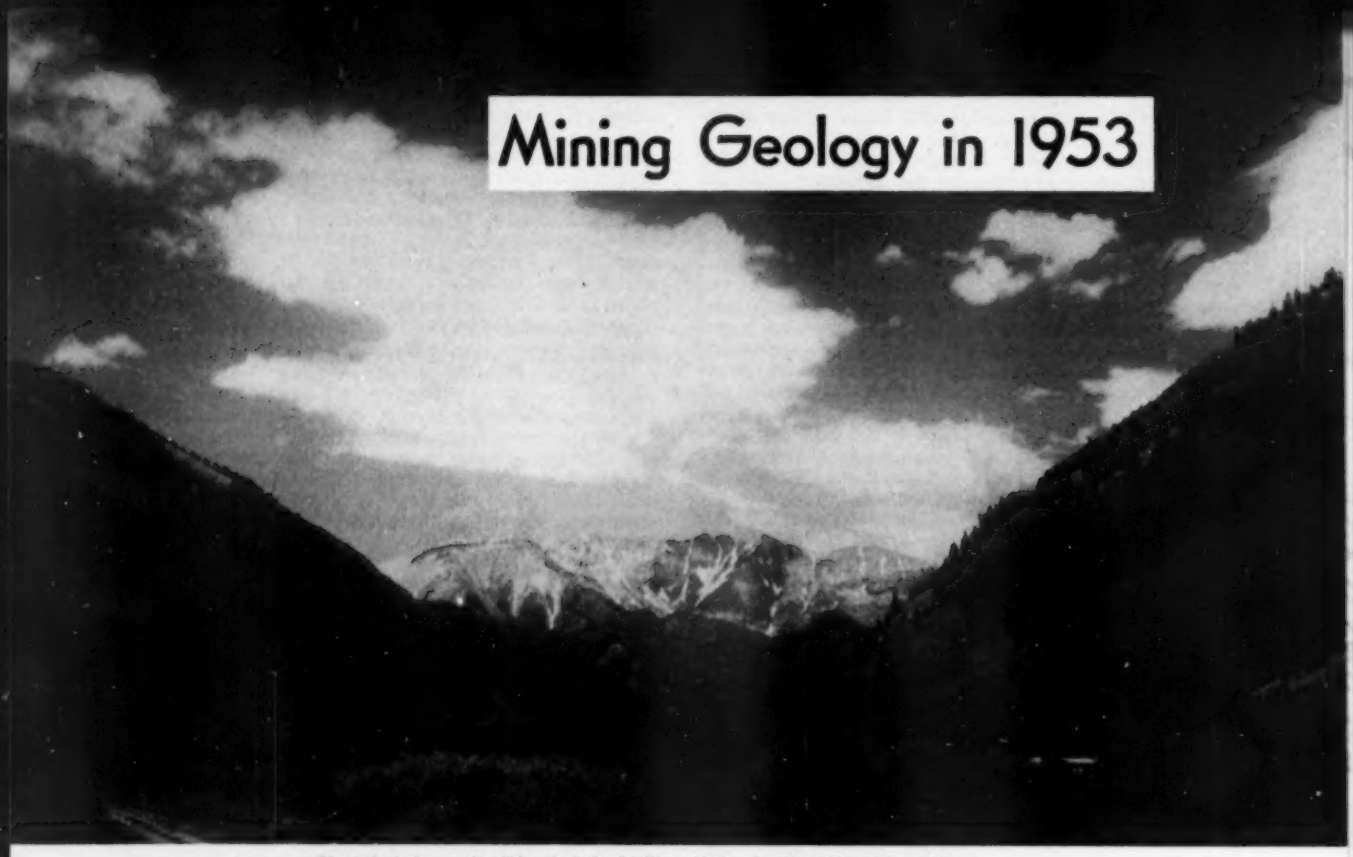
In midsummer IMC began operating its new HCl-MgO plant at Carlsbad, built to utilize byproducts of IMC's potassium sulphate refinery.

Finis

A writer of this review some years back said then that beneficiation was developing so fast that no one could hope to keep abreast of technical matters without the value of friendships and informal visitations at conventions. We heartily agree—technical meetings are a clearing house for an exchange of ideas, and this is progress.

We take this opportunity to express our thanks to fellow MBD'ers who responded to our request and submitted information for this review.

Mining Geology in 1953



"A geologist's paradise," head of the La Plata Valley, La Plata Mountains, Colorado.

by George M. Schwartz

WHEN reviewing the progress made in mining geology for the year 1953, one might say that not much has been accomplished and, indeed, in a subject such as economic geology not much progress should be expected in the 10 months of the year which elapsed before this article was prepared. This seeming lack of progress, however, disappears when the facts are investigated a bit. There undoubtedly are more economic geologists at work than ever before. It is probably not an exaggeration to say that more geologists are now employed by a single company in the Lake Superior district than were employed in the whole district 20 years ago.

In most mining districts geologists are busy with numerous problems of production, development, and exploration and some give an occasional thought to the scientific problems of the science, or rather the art, of mining geology. In fact, this very intense activity of mining geologists is one reason why progress seems slow; they do not have time to write up results of investigations. There is also a great amount of work being done which is not released because of company policy. Conditions have improved very much in recent years but mining corporations, in general, have some distance to go before attaining par with the petroleum industry in this respect.

An excellent example of the value of pooled information is furnished by a paper on sedimentary volumes in the Gulf Coastal Plain of U. S. and Mexico. Several oil companies contributed the results of geophysical operations and three companies prepared the data thus furnishing much more adequate idea of the volume of sediments than was ever available previously (see *Bulletin Geological Society of America*, vol. 63, p. 1115-1228).

In another recent example of cooperation about ten petroleum companies combined to validate a new method of density logging which would be of great help in exploration but required a rather large expenditure for one company to undertake alone.

Map of the Mesabi

It would be inaccurate, however, to leave the impression that mining companies do not cooperate. The Minnesota Geological Survey has in preparation a bulletin which will contain a large scale structural contour map of the Mesabi Range toward which every operator in the district, without exception, contributed all data available from his work. The result is a much better understanding of the structural control of the iron ore deposits of this great district, and also a more adequate idea of the conditions of sedimentation which resulted in the Biwabik iron-bearing formation.

By no means all of the research work by the companies is to be kept confidential indefinitely, but often it is a case of caution in releasing results until the most careful validation is completed. An example that has come to the writer's attention is a remarkable amount of valuable chemical analytical work on disseminated copper ores at Morenci, Bisbee, and Tyrone by the chemists and geologists of the Phelps Dodge Corp. Eventually much of the data will be released and will constitute a major contribution to the knowledge of the chemical composition of porphyry ores and protores.

Perhaps the most significant scientific advances in geology in recent years has been in the field of petrology and, because of the close relation of petro-

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logy to mining geology, many of the principles developed by petrologists are either directly, or indirectly applicable to problems in metal deposits. One needs only to look casually through such texts as Barth's *Theoretical Petrology* and Ramberg's *The Origin of Metamorphic and Metasomatic Rocks* to appreciate their possible impact on the thinking of economic geologists. Particularly applicable are the chapters in Ramberg entitled "The Mechanisms of Metasomatic Transfer of Matter Through Rocks" and "Metasomatism."

In recent years the permeability of rocks has been investigated with some vigor, Uhle's paper in *Economic Geology* of 1951 being especially noteworthy. During 1953 Maxwell and Verrall in a paper in the *Transactions of the Geophysical Union* showed that expansion, and therefore permeability, of carbonate rocks increases greatly with temperature thus perhaps helping to explain the receptivity of limestone as a host rock which has been effective in mesothermal and pyrometasomatic deposits.

The recovery of scientific geological work in Germany is emphasized by the availability in the U. S. during the year of *Erzmikroskopisches Praktikum* by Han Schneiderhohn which with Ramdohr's *Die Erzmineralien und ihre Verwachsungen* (1950) brings up to date the earlier works by these authors.

The March-April issue of *The American Mineralogist* is a good example of the intensive mineralogical work now being carried on in many laboratories. Some of this work is of direct interest to the economic geologist. For example, the paper by Cameron, Rowe, and Weis on *Fluid Inclusions in Beryl and Quartz* brings out the difficulty in determining the temperature of origin of minerals on which estimates of the temperature of origin of some ores are largely based. Quotes from their conclusions are as follows. "Inclusions in quartz have proved unsatisfactory for temperature studies, because most of them fracture and leak when heated.

"Decrepitation curves for quartz in pegmatites are significant only when bursting can be correlated precisely with various types of inclusions, when the inclusions can be shown to consist of aqueous solutions, when bursting or leakage can be shown not to have taken place, and when the effects of primary inclusions are not masked by those of secondary inclusions."

At the Toronto meeting of the geological societies in November the contributions of the mineralogist, chemists, and physicists were particularly noteworthy. The work on age determination of rocks is proceeding rapidly and soon reasonably good determinations of the relative ages of igneous rocks should be available. The close cooperation of the mineralogist, geochemist, petrologist, and economic geologist holds best hope for the solution of some complex problems of ore genesis.

Face of taconite at west end of Reserve Mining Co. pit, Babbitt, Minn., shows gentle southerly dip and massive rock.

Problem of Alluvium

Geochemical prospecting continues to receive attention from several quarters and the new data furnish a continually improving basis for its application. Otis M. Clarke pointed out that soil under trees contains about the same amount of copper as the ash of leaves owing to the copper added by decaying leaves over the life of the tree. He also showed that at Ray, Ariz., soil samples outline the orebody fairly well and that diabase and similar basic rocks retain more copper than siliceous rocks.

One of the most significant achievements during the year has been the beginning of mining of ore as part of development of the Pima mine south of Tucson, Ariz. It is reported that 26,000 tons of ore assayed 5 to 6 pct copper. The discovery of this deposit under 200 ft of desert alluvium proves, what has long been suspected, that hidden ore deposits lie beneath the desert alluvium of extensive intermontane valleys of the Basin and Range province. The discoverers are to be congratulated on proving that a good geologic possibility, and intensive geophysical work can be made to pay in some cases.

It would be a mistake, however, to consider that the problem of the alluvial valleys has been more than scratched. In the first place much of the area of these valleys is underlain by far more than 200 ft of alluvium and the difficulty of geophysical work probably increases somewhat as the square of the depth beyond 200 ft. In the area south of Tucson, moreover, the deposits are mainly of the pyrometasomatic type in which magnetite is frequently present. Magnetic methods are therefore applicable, whereas in the mesothermal deposits, the abundant type in Arizona, epigenetic magnetite is rarely, if ever, found and primary magnetite has been largely altered to pyrite or martite.

New Ore from Old Areas

It is possible that a zone of low magnetic intensity may be a guide to ore seems to be true over the area of the San Manuel deposit. Hydrothermal alteration in some locations may have destroyed the original magnetite in a rock without depositing ores. Obviously, caution and as many checks as possible are needed in searching for ore.

An excellent example of the value of sound geologic study in finding new ore has been noted in an old district in Vermont. Close attention to the geologic picture by the staff of Vermont Copper Co. has been of inestimable aid in mining operations permitting greater ore extraction, and less wasted effort in development. Even more important was the discovery of a new vein on the west limb of the synclinal structure. Furthermore, regional geologic studies have indicated other possibilities with the result that No. 3 vein has been traced for 1000 ft with an indication of ore of the average grade in the present producing vein. Other possibilities remain.

A somewhat similar example of the value of sound geologic inference followed by intensive exploration is furnished by the geologists of Pickands, Mather & Co. of orebodies lying at depth beneath four adjacent mines in the Gogebic district which had presumably been exhausted.

The announcement of the discovery of a very large base metal deposit in New Brunswick close to an abandoned pit of an iron mine is significant because it centers interest on a geologic province not noted for its metal production. It also raised the question of the nature of the expression of this orebody. Was there evidence of the existence of the zinc-lead sulphides in the pit of the old iron mine? If so, what was the evidence and how should we use similar evidence to help find other deposits?

Iron Ore

One of the most interesting developments in iron ore geology in recent years has been the exploration of many deposits in the Grenville rocks of southeastern Ontario where Bethlehem is preparing to mine and concentrate the magnetite of the Marmora deposit. These deposits in general are of the pyrometasomatic type but localization at the contact of intrusions seems to be the exception rather than the rule. The metamorphic rocks in which the magnetite bodies occur are extremely complicated and contain a wide range of metamorphic silicate minerals. Although some of these deposits have been known for a century, new ones are being discovered following the indications furnished by aeromagnetic work. The nature and origin of the deposits are not well understood and results of studies now in progress by the Canadian Geological Survey will be awaited with interest.

Some geologic information on the Bomi Hill iron deposit was published during the year by E. F. Fitzhugh, Jr. Although the deposit is associated with an iron formation, the high grade hematite-magnetite ore is attributed to replacement by hydrothermal processes near the close of a period of granitic invasion. This adds another iron deposit to the growing list of those believed to be a result of replacement, rather than negative enrichment. The Steep Rock Lake deposit is a conspicuous example as has been emphasized by Roberts and Bartley.

The deposit at the Bethlehem Steel's Grace mine is another massive replacement body of iron ore, in this case in Paleozoic limestone underlying the Triassic sediments of the area. This orebody also furnishes an example of the success of new techniques as an aid to geology because this deposit does not extend closer to the surface than 1500 ft.

Ventures reported optimistically on the results of exploration of the high grade iron deposit at Fort Gourand, Mauritania, French West Africa. It was anticipated that the minimum of 100 million tons necessary to justify mining can be outlined.

Mentioning iron ore reminds one that a statement in the May issue of MINING ENGINEERING says that Fenimore plans to develop concentrating ore near Ungava Bay. If this operation can make a profit under arctic conditions, low grade iron ores the world over will merit another look.

The close relation of applied geology and applied geophysics is emphasized by many developments during the year and a striking evidence of this relation was furnished by the changing of the name of the Dept. of Geology at Massachusetts Institute of Technology to Dept. of Geology and Geophysics.

Secondary sulphide enrichment is an old story and not much emphasis has been placed on it in recent years but the new open pit at Ray brings to mind that some of our great western deposits owe their commercial ore to this process. At Ray practically all the ore has been enriched so that primary protore became mineable ore. A diabase sill has acted as a dam to the supergene solutions and no ore has been found beneath it. Morenci, Castle Dome, and the new Lavender pit at Bisbee are other examples of deposits where the mineable ore has all been formed by enrichment of very low grade pyritic rock.

Africa continues to come to the fore as a mineral producer. Long the leading gold producer among the continents it seems in no danger of losing its place, but on the contrary, is destined to produce an even greater proportion of the world's total new gold as developments in the Orange Free State and the far west Rand add large reserves of ore. All of these gold deposits including the main Rand also will produce important amounts of uranium.

Other deposits in Africa being developed, or adding new reserves, include the manganese deposits in West Africa and Angola, asbestos in South Africa and Southern Rhodesia, chrome in Southern Rhodesia, iron ore in Liberia and Mauretania, tin in Belgian Congo, copper in Belgian Congo and Northern Rhodesia, cobalt in Katanga and large lead deposits in North Africa.

Of importance is the geologic work for the Portuguese Government in Angola and Mozambique being done by the E. J. Longyear Co. With modern methods of aerial photography as well as air transport, far more can be accomplished in reconnaissance geological work than ever before.

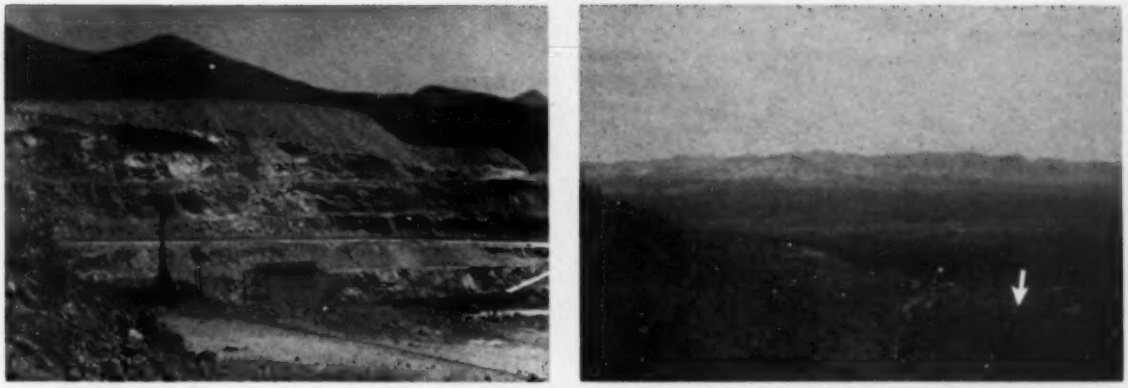
A Widening Search

Mining companies have spread their activities over many parts of the world in the past but certainly there has been a great increase in this type of activity since World War II. In this respect 1953 has probably been a banner year. Some of the larger companies are taking a good look at areas which a few years ago they probably considered of no interest. Many small companies are not to be outdone but also are working far afield in an attempt to find deposits which will greatly prolong their life.

The extent of the widespread nature of exploration and development is well illustrated by the Ventures Ltd. 1952 Annual Report (April 30, 1953). Three maps show the distribution of 49 separate holdings in Canada and the northern U. S., Africa, and South America. These include deposits of nickel, copper, gold, silver, lead, zinc, iron, cobalt, uranium, columbium, graphite, nepheline, syenite, and petroleum. In the body of the report one learns of an interest in manganese, molybdenum, tungsten, tin, titanium, lithium, sodium, zirconium, magnesium, cadmium, calcium, and pyrite. With operations of this kind well financed and under the control of an experienced staff there can be little doubt that the supplying of mineral products to the Free World is in good hands.

The search for deposits of uranium has continued with unabated zeal and reports of new finds indicate that not all of the work is in vain. Although production figures are not published, such scattered information as is available suggests that problem of an adequate supply of raw material is on the way to being solved. The conclusion seems evident that the available supply of any mineral will respond quickly to a sufficient financial stimulus.

The age of discovery of deposits by use of a little initiative on the part of prospectors is not completely over. An interesting and important example is the discovery by A. E. Cumley and Lester Thomp-



PRODUCER—Benches on north side of Lavender pit, Bisbee, show leached porphyry, subject of intensive, continuing geological study. NEWCOMER—Geology also carries the burden new production. Right: Eastern part of San Manuel area before disturbance of natural conditions; arrow points to only outcrop.

son of the Crystal Mountain fluorite deposit in Ravalli County, Montana. These deposits showed as bare spots on aerial photos and were first noted in 1936 but their true nature was not recognized until 1951. Exploration by the U. S. Bureau of Mines showed that the largest spot contained a fluorite deposit 180 by 270 ft in surface dimensions, and five others are known ranging in size down to 20 by 60 ft. These are remnants of low-angle tabular orebodies left at the crests of ridges because of resistance to erosion.

Publication of the Professional Paper No. 256 *Geology of the San Manuel Copper Deposit, Arizona* which contains a summary of the history of the deposit emphasizes the enormous amount of work and expense involved in the discovery, exploration, and development of a large mineral deposit. The preliminary report on the property for the U. S. Geological Survey was made by B. S. Butler and N. P. Peterson in March 1943 and the U. S. Bureau of Mines began drilling in November 1943. Latest reports indicate that production may begin in 1955 so 12 years will have elapsed between the first expense and any return on the investment.

Mine models have been a perennial means of geologists and engineers expressing their inventive genius. How to make a better model is described by Earl Phillips who used thin acetate sheets supported by a grid of piano wire on an aluminum frame and illuminated by fluorescent lighting. The writer has seen fluorescent paints used effectively on a model.

The USGS

The work of the U. S. Geological Survey on ore deposits continued without radical change during the year. A large part of the economic work of the survey continues to be devoted to problems involving uranium and defense minerals examinations. Probably much of this work is desirable but if one takes the long view it is unfortunate that such a large part of the effort is devoted to work of only minor significance as is necessarily the case with examinations for DMEA. Throughout most of its existence the survey has been the principal investigator of scientific problems in the metal mining districts. Since the beginning of World War II this type of investigation has been continued in only a few districts, notably the Keweenawan Copper, Iron River, Tintic, Globe-Miami, Jerome, Silver City, Coeur d'Alene, and San Manuel districts.

If one doubts that the main geologic effort of the survey has drifted away from the broad study of districts, he has only to study the monthly publication lists of the survey for the period January to September. During this period, of the published professional papers (or parts of volumes), 7 were primarily concerned with economic geology, 13 with paleontology, and 2 with other subjects. The bulletins showed more emphasis on economic geology with 12 in that field and 5 in other fields. Of the circulars 7 were concerned with economic geology other than uranium, 29 with uranium, 23 with water, and four with other subjects. No publication on a major mining district appeared during the period summarized above, but the Professional Paper No. 235 *Geology and Ore Deposits of the West Slope of the Mosquito Range, Colorado* was issued in December.

It is to be hoped that we will not be in a state of emergency indefinitely, justifying so much work of temporary importance, in order that a larger share of the effort can be put in projects which will maintain the high standards of previous survey work. As one survey geologist expressed it, "We are drawing on our bank of knowledge of ore deposits and are not depositing new knowledge anywhere near fast enough."

It is probably rare to find a real pessimist among mining geologists at the present time. All predictions are for great industrial expansion during the next decade and an increase of 20 pct in the production of metals during that time seems conservative. If production is to be increased by that much, and reserves are to keep pace, then mining geologists and engineers are going to be indeed busy. Recent summaries show that mining engineers, metallurgists, and geologists are now in short supply and the present registration in schools giving courses to train new men is not great enough to take care of the increased demand. This problem, and the steps being taken to supply well-trained mining geologists by the Colorado School of Mines, was discussed by Kuhn and Carpenter in the March number of the *Mines Magazine*. The problem of getting a sufficient number of students into courses in mining, geology, and metallurgy is a serious one. One of the most obvious steps which the mining companies can take to help alleviate this situation is to supply funds for scholarships. There has been an increase in the number of scholarships during the past two years, but the need is great and the number inadequate. The problem demands earnest attention.

The writer is indebted to Dr. D. M. Davidson for helpful suggestions in the preparation of this review.

United Geophysical Co. has continuous recording total intensity magnetometer mounted on special all-wheel drive vehicle.

by Kenneth L. Cook

GEOPHYSICAL exploration is continuing to expand in scope and variety of methods, in experimental studies of specific applications, and in development of theory for complex situations. Aerial surveys have been made economically more attractive by simultaneous recording of magnetic and radioactivity data, and aerial electromagnetic surveys have been attempted. The most significant success of mining geophysics was the discovery of huge lead-zinc-copper sulphide ore deposits in New Brunswick, Canada. Spectacular geophysical activity has occurred in the area as a result of these discoveries, and geophysics is expected to continue to play a large role in this drift-covered area.

Other developments this year find the Atomic Energy Commission making available monthly reports of the location of anomalous radioactivity detected in aerial and ground surveys and the AEC is installing supersensitive radioactivity assaying instruments in about 25 localities in the U. S. Interest in helicopters is being aroused because of potentialities for near-ground surveys and better location control of anomalies. Japan can be added to the list of countries using geophysical surveys extensively.

Geochemical prospecting, rapidly established as a valuable prospecting tool, has probably advanced more than any other type of exploration. A large area of low grade copper mineralization has been discovered in British Columbia through the application of the geochemistry of natural waters. Geochemical prospecting by mining companies and private individuals is in progress in the U. S., Canada, England, Finland, and Australia. The U. S. Geological Survey has devised field tests for 15 trace metals, a truck-mounted unit for spectrographic analysis is nearing completion, and an annotated bibliography of world literature on geochemical prospecting has been published.

Outstanding ore discoveries have been made by airborne magnetometer and radioactivity surveys in the U. S., Canada, and Australia. In all the discovery areas ground geophysical surveys were used to further delineate the anomalies and orebodies. An innovation is reported in the use of electrical methods to eliminate potential ore-bearing areas in the selection of a townsite in the huge sulphide area in New Brunswick, Canada.

The large number of geophysical or geochemical surveys (101 in all) submitted during 1953 to the Quebec Dept. of Mines for assessment work credit is significant evidence of the importance of these methods in ore prospecting.

KENNETH L. COOK is Geophysicist, University of Utah, Salt Lake City.

Research and Development

A gravity survey across central Vermont and New Hampshire by R. J. Bean indicates a number of negative anomalies with magnitude as great as 50 mgals; most of these are correlated with crustal downwarps or deep granite masses either intruded or uplifted in the area. Gravity maxima occur principally over the Green Mountain anticlinorium and the basic rocks of the Ossippee Mountain ring-dike complex. A regional gravity survey comprising 1300 stations in the southern half of the Sierra Nevada was made by the USGS and Harvard University. The Geological Survey of Uganda made gravity surveys of the Ruwenzori Mountains up to about 12,000 ft in order to assist the geological interpretation of the relations of the mountain mass to the Albert Rift Depression. The Compagnie Général de Géophysique reports successful application of Baronov's method of determining the vertical gradient of gravity to the interpretation of gravity anomalies taken at sea, in relatively shallow water. S. Thyssen-Bornemisza has evolved a new trailer-mounted gravimeter for measuring the vertical gradient of gravity, capable of an accuracy of about 10^{-4} cgs.

The effects of some complicated structures of the subsoil on telluric currents were investigated theoretically or by small-scale experiments, by J. Kunetz and J. Chastanet de Gery. Additional interest in the telluric-current method may be revived as a result of a theoretical discussion of the magneto-telluric method by Louis Cagniard.

The airborne survey program of the USGS has been stepped up by the acquisition of a second DC-3 aircraft in which magnetic and radioactivity detection equipment have been installed. The USGS and Oak Ridge National Laboratory have jointly investigated absorption and scattering of gamma radiation at distances of several mean free paths from a source. These data, when evaluated, may ultimately improve the interpretation of radioactivity measurements made from aircraft. J. C. Cook has outlined theoretical equations and curves for several types of radioactivity anomalies at various flying heights. He recommends low flying heights, especially by helicopter. Supersensitive radioactivity assaying devices developed by the AEC are measuring uranium oxide contents as low as 0.05 pct.

Using facilities of the Naval Ordnance Laboratory, USGS geophysicists experimented to obtain magnetic fields of laminal models to be used in constructing fields of magnetic doublets in the analysis of total magnetic intensity anomalies. Chemical analyses and magnetic measurements on rock specimens from the Adirondack Mountains show a clear relationship of direction and intensity of remanent magnetization to the chemical composition of the metallic oxides in the rocks. All rocks showing reverse remanent magnetization contain an intimate intergrowth of hematite and ilmenite.

L. W. Morley, after an investigation of time and distance variations of the earth's magnetic field in the auroral zone, concluded that corrections for the time variation such as magnetic storms in aeromagnetic surveys, could be made from data obtained at a ground station located centrally within the survey area, but that corrections were seriously in error for stations located 87 and 138 miles apart.

Magnetic recording of seismic data has expanded, and a greater number of channels are now recorded. Almost any combination of filtering, attenuation, and mixing is now possible, greatly improving interpretation in difficult areas. The Minnesota State Highway Dept., and R. A. Kaasa, at the University of Minnesota, are both working on seismic refraction instruments using a sledge-hammer source and electronic timing to determine depth to bedrock. Attenuation of seismic waves in soft ground, and the influence of clay content of cores on the self-potential of the Bradford sand have been studied at Pennsylvania State University. Scale-model studies of seismic propagation problems have been undertaken at Columbia University, and considerable progress has been made in modeling the various types of surface waves commonly observed. R. M. Tripp reports that the lateral variation of vertical seismic velocity gradients were used to determine zones of alteration and other local stratigraphic variations in mining areas.

Dominion Observatory, Ottawa, has undertaken the construction of 12 field seismographs which will be connected by radio links to a central recorder. The seismometers are moving coil instruments with a period of one second, whose output is used to modulate the frequency of an audio-subcarrier. The audiofrequency is transmitted to the recording station by means of standard 2-meter phone transmitters. The equipment is intended for earthquake and explosion studies, using seismometer spreads extending up to 30 miles on either side of the recording station. Satisfactory field tests on a 3-channel prototype have been completed, and it is hoped that the full 12 channels will be in operation during the summer of 1954.

Well logging has taken a big step with development of instruments for logging detailed seismic velocities of sections as thin as 5 ft in deep holes. In the Williston Basin 500 to 1200-ft core holes were surveyed, both electrically and for seismic velocity, with combination truck by Schlumberger. The newly developed magnetic logging instrument is being successfully used as an aid in various types of logging problems. T. Koulomzine reports development of equipment for surveying deep diamond drill holes by the induced potential gradient method.

Research at McMaster University, Canada, on statistical methods applied to the spectrographic study of shales for gallium, appears to be applicable to sampling, analyzing, and comparing results of geochemical exploration for ores.

Trends

More mining companies are setting up their own geophysical exploration departments. One mining company alone reports an expenditure of $240,000 for geophysics in 1953. An increase in the use of gamma-ray, self-potential, and resistivity logging of exploratory drill holes is reported. Although seismic prospecting (principally for oil) is reported to have declined slightly in the U. S. in 1953, an increase in the use of gravity, radioactive, and geochemical, and other methods is apparent.

Increased interest in regional geophysical studies has been noted. The trend is toward improved instruments, and development of theoretical equations and curves for analysis of more complicated natural conditions, using conventional procedures. More continuous-recording instruments and lighter and more portable equipment are being developed. The usefulness of magnetic tape recording as an aid to seismic interpretation in difficult areas has been demonstrated. A greater variety of well-logging methods, including the newly developed continuous velocity log, are being used and improved.

Current research in geochemistry is tending toward detailed comparison of water, soil, plant, and rock geochemical methods and toward better correlation of geochemical methods with geological and geophysical prospecting methods. This should soon yield valuable information on optimum use of these methods in combination.

World Review

United States

In the U. S. geophysical search for minerals and fuels continued to increase during 1953. Several large mining companies expanded their geophysical programs and increased personnel. Several major geophysical contractors established separate divisions to handle mining geophysical work as opposed to petroleum work.

COLORADO PLATEAU—Airborne radioactivity reconnaissance by the Anaconda Copper Co., AEC, and USGS in the Grants, N. Mex., district revealed anomalies which led to several important discoveries. A ground Geiger-counter survey in 1949 first detected the presence of significant quantities of uraninite in the Sunshine mine, Idaho. A later scintillation detector survey by the AEC indicated a radiation pattern which corresponded generally to the mineralized areas. About 12,000 miles of aerial scintillation counter traverse were completed by the USGS in 1953.

Seismic refraction and electrical resistivity surveys

were made by the U. S. Bureau of Reclamation for the AEC in Monument Valley, Ariz., to locate ancient buried channels which may contain uranium deposits. In the course of a seismic survey by USGS in Monument Valley, a shallow reflection from a depth less than 40 ft was recorded on conventional refraction equipment. Combinations of surface and inhole resistivity measurements were employed experimentally on the Colorado Plateau to map lateral extensions of high resistivity layers found in association with carnotite mineralization.

Regional gravity and aeromagnetic surveys are underway in the Colorado Plateau area to gain information on basement configuration, buried intrusives, and major structural features, and to determine if these are related to the deposition of uranium. Studies of Plateau uranium ores in their original state aim to provide basic physical and chemical data on the ore and country rock. Special drilling methods are used to obtain cores in which the amount and composition of the interstitial water have not been changed radically.

The USGS is conducting a regional survey in the Mojave Desert, California, involving gravity, ground and airborne magnetic, seismic, and radioactivity methods, to study the configuration of Tertiary basins, sediment-filled playa lakes, and related structures. Aeromagnetic surveys of an area in southwest Washington have been made to determine Miocene structures reflected in the attitudes of the intercalated basalt.

WESTERN ORE SEARCH—New discoveries of high grade iron ore in the Lovelock area, Nevada, were made with United Geophysical Co.'s mobile, continuously recording ground magnetometer. Kaiser Steel Co. made a magnetometer survey of about 3500 stations at its Eagle Mountain iron mine in southern California. When correlated with previous drilling and geology, this work greatly facilitated the selection of proposed drill holes for a pit plan. Additional geophysical and drilling exploration by the United Geophysical Co. has extended the known reserves of the Pima mine in Arizona where the orebody was originally discovered by geophysical methods.

Resistivity, self-potential, magnetic, geochemical and biogeochemical methods were tested over known ore deposits and structures in the Park City area, Utah. Resistivity methods delineated some geologic structures, but did not indicate mineralized veins. Residual soil samples tested for zinc indicated mineralized veins but also indicated some noncommercial areas.

TRI-STATE AREA—The USGS used horizontal and vertical resistivity profiles to map slump structures in the Tri-State lead-zinc mining district, Cherokee County, Kan. Lateral resistivity effects obtained in the field agree well with the corresponding theoretical resistivity curves computed for filled sinks of elliptical or hemispherical shape. A brief seismic refraction survey was made in a successful attempt to locate shale slumps in the same area.

The Missouri Geological Survey made a ground magnetic survey in Crawford County for control on anomalies discovered in an aeromagnetic survey. Private geophysical studies were made in the Joplin district, and in Crawford County, Mo. The National Lead Co. continued to use magnetic and electrical methods successfully in the Fredericktown district. Three orebodies were found in an area that a magnetic survey indicated to be structurally favorable for mineralization. A resistivity survey established the limits of mineralization in another area and resulted in a considerable saving of drilling costs by eliminating the need for pattern drilling. W. M. Barret Inc. reports electromagnetic surveys for sulphide in Missouri lead belt and Rocky Mountain region.

IRON ORE—An aeromagnetic survey totalling 6500 traverse miles in the northwestern part of Minnesota was completed by the USGS and gravimeter surveys of the Iron Ranges were made by several companies. In the Cuyuna district ground magnetic measurements in drift-covered areas were used to obtain information on stratigraphy and structure of the iron formation and associated formations. A study of a nickel-copper area in the Duluth gabbro was made using several geophysical methods.

Jones & Laughlin Steel Corp. reports increasing use of geophysics in exploration and development work. Future plans call for research, as well as wider application of present methods to the exploration for iron ore, especially of low grade. Surveys were conducted in the Lake Superior region, the Adirondack Mountains, and Canada, using various methods.

A regional gravity survey of the Michigan Upper Peninsula has been completed by the Michigan College of Mining and Technology. Previous work in the eastern half of the Upper Peninsula, and detailed gravity and magnetic investigations near Calumet delineated a rhyolite porphyry intrusive located by the airborne magnetometer. The detailed study established that economic values associated with the intrusive were extremely low.

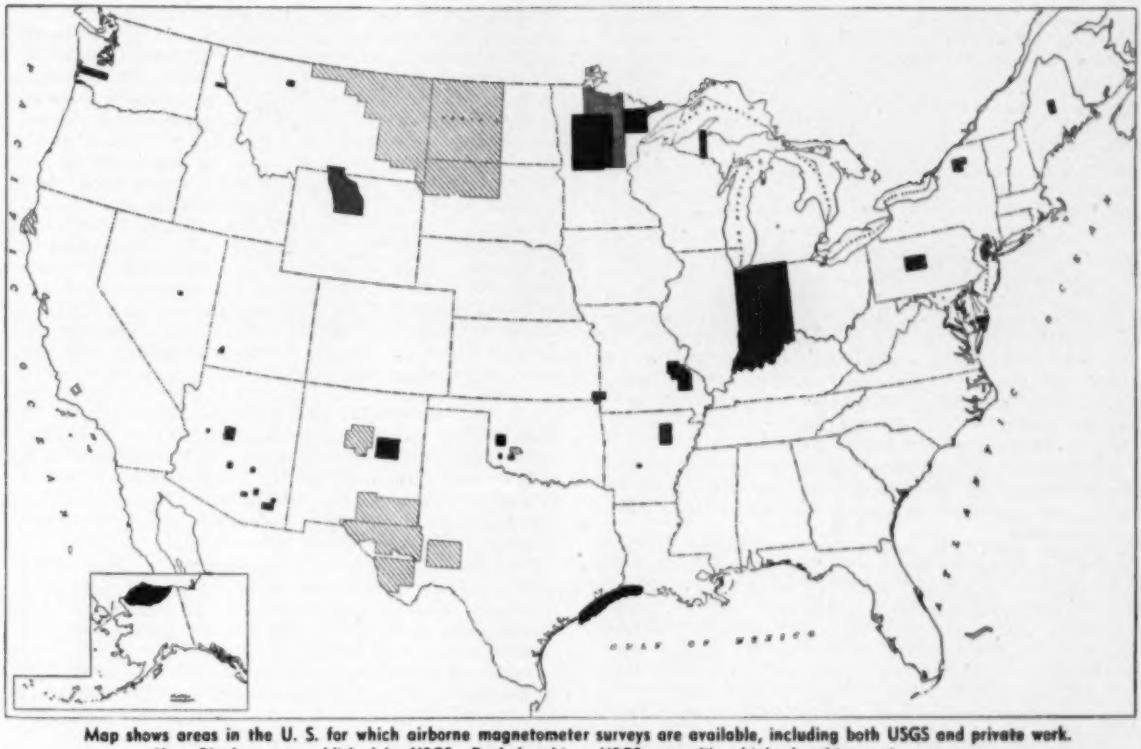
EASTERN ACTIVITY—Johnson & Straley Ltd. report magnetic and electrical surveys for iron ore and electrical surveys for lead ores in the southern Appalachian Mountains. Bouguer gravity anomalies have been mapped for large parts of central and northeast Pennsylvania by Pennsylvania State University and others, and are being used to help interpret the regional tectonics of the Appalachian Mountains. Magnetic surveys in Aroostook County, Maine, located and traced manganiferous zones which contain magnetite. These zones were later drilled by the USBM.

AEROMAGNETIC SURVEYS—Maps for several large areas of the country have been released to the public by the USGS, and private aeromagnetic surveys of the Williston Basin, parts of the Delaware Basin and Marathon uplift, and a number of smaller areas were released in 1953. *(See map.)*

GROUND-WATER STUDIES—The effective use of geophysical methods in the study of ground-water problems is now becoming widespread, and many successes are reported. Successful determinations of the location of adequate municipal water supplies by resistivity methods is reported in 92 pct of cases investigated by the Illinois Geological Survey. Many municipalities in Illinois derive their total water supply from sand and gravel discovered by resistivity methods in glacial drift. The Kansas Geological Survey is making preliminary resistivity surveys for the location of ground water. Resistivity surveys by the U. S. Bureau of Reclamation were 80 pct successful in determining ground-water conditions in glacial drift in a large test area in South Dakota. Resistivity methods were also successful in determining possible seepage from a canal in Nebraska.

Hydrologic, geologic, and geophysical studies conducted jointly by the USGS and the New Mexico Institute of Mining and Technology near Santa Fe, N. Mex., established several good correlations of the occurrence of ground water and the general distribution of deformed geologic units concealed below more than 200 ft of unconsolidated sediments.

HIGHWAY CONSTRUCTION—Geophysical methods have been employed in more than 33 of the 48 states in connection with highway construction and other engineering works. The Physical Research Branch of the Bureau of Public Roads has conducted subsurface surveys and performed extended demonstration tests in 27 of these states with the result that there are now 18 state highway departments possessing geophysical equipment or having a cooperative arrangement for use of geophysics in obtaining preliminary information on subsurface conditions. In addition, nine other states are in the process of building suitable apparatus, acquiring apparatus, or have shown increasing



Map shows areas in the U. S. for which airborne magnetometer surveys are available, including both USGS and private work. Key: Black areas, published by USGS—Dark hatching, USGS open file—Light hatching, private surveys.

interest in the possible use of geophysics. Most of the work has been done by the electrical resistivity method. And only two states, U. S. Bureau of Public Roads, and the USGS have made use of the refraction seismic test to any great extent in connection with highway work. Earth-resistivity tests have been utilized on most of the major toll-road projects now constructed or being planned. Representatives of government and private engineering agencies from Turkey, Pakistan, Brazil, Ecuador, and Southern Rhodesia have studied methods used by the U. S. Bureau of Public Roads.

ENGINEERING—The U. S. Bureau of Reclamation determined the depth to bedrock at the Oso damsite, Colorado, by seismic refraction. Refraction seismic profiling was continued by the Geological Survey at Lake Roosevelt, Wash., to study bedrock configuration and its relationship to landslides.

Sherwin Kelly reports extensive spontaneous polarization and magnetic surveys for ores in Arizona, resistivity surveys in Missouri to investigate foundation conditions at a proposed plant site, and a survey to investigate the deformational characteristics of bedrock. Resistivity depth profiles were used to map buried pre-glacial channels in bedrock in New Jersey.

Gravity studies were conducted on the Greenland ice cap to study the topography of the underlying rocks as part of a geophysical program including seismic work conducted for the Army under the direction of Stanford Research Institute.

GEOCHEMISTRY—Experimental geochemical studies were conducted in ten major mining districts last year by the USGS and at least six crews are now in the field, as well as about 25 private crews. Soil sampling has proved most effective, but botanical methods were successful as guides in exploration in several districts. In some areas it has been found that traces of metals migrated upward from bedrock sulphides, through glacial or alluvial materials. Trenching on the basis of high cobalt concentrations in surficial soil revealed a belt strongly mineralized by cobalt in a previously unknown, unexplored area in the Blackbird cobalt district, Idaho. A contrast of as much as 1000 ppm cobalt compared to a background of 20 ppm was found in known mineralized areas. The content of cobalt and copper in stream sediments was also found to correlate with that of soil in the drainage basins. In the Wisconsin-Illinois-Iowa zinc-lead district, the heavy metal content and MgO/CaO ratio, and locally, the percentage of insoluble materials of the limestone, were found to increase near ore.

Trace analyses of the Tapeats sandstone of Cambrian age, which indicate up to 100 ppm of copper in areas near the underlying pre-Cambrian copper deposits near Jerome, Ariz., suggest the possibility of chemical prospecting for buried deposits in this area.

At Ray, Ariz., the copper content of oak and mesquite leaves and soil derived from the leaves was found to be a good index to the occurrence of copper mineralization in the underlying rocks, although certain geologic and topographic conditions can give wrong results. Smelter smoke apparently causes abnormally high values. Uranium content of needles and twigs of conifers growing on the Todilto limestone, and the distribution of selenium-concentrating plants on Jurassic sandstones are indicated as guides to uranium mineralization near Grants, N. Mex.

Mining companies at Cobalt and Cour d'Alene, Idaho, and at Tintic, Utah, have continued successful geochemical investigations pioneered by the USGS. Exploration is continuing in areas of the Thompsons district, Utah, which were previously mapped as botanically favorable from indicator plant studies. Several orebodies were recently discovered. A geochemical survey for niobium was conducted near Magnet Cove, Ark.

Canada and Alaska

NEW BRUNSWICK—Twenty aeromagnetic map sheets, covering about 8500 sq miles of western New Brunswick, were published in 1953 by the Geological Survey of Canada. Three important electromagnetic anomalies were found to be underlain by important lead-zinc sulphide deposits in the Bathurst area. More than ten companies are conducting further exploration and electromagnetic surveys on nearby aeromagnetic

anomalies. Resistivity and ground magnetic methods are also being used, and geochemical soil tests have been successful in determining which anomalies are underlain by valuable metal sulphides. Anomalies discovered by spontaneous polarization methods are checked by gravity surveys to differentiate sulphide from graphitic rocks, according to Sherwin Kelly.

ONTARIO—An aeromagnetic anomaly near Marmora, discovered by the Geological Survey of Canada and the Ontario Dept. of Mines, was confirmed by a dip-needle survey. The anomaly was found to be underlain by a large magnetite orebody covered by limestone and drift. Geophysical anomalies at Steep Rock Lake, Ont., indicate several potential iron-ore zones. Aeromagnetic Surveys Ltd. made aerial magnetometer and radioactivity surveys for the Ontario Dept. of Mines in Thunder Bay and Parry Sound districts. A total of 1376 sq miles was surveyed, and maps have been published. Sixteen aeromagnetic map sheets, covering part of southern Ontario east of Georgian Bay, were published in 1953.

Spontaneous polarization and magnetic surveys for copper and nickel deposits at the edge of the Sudbury basin, and a resistivity survey for gold quartz veins are reported.

QUEBEC—Exploration of the large Labrador-Quebec iron-ore districts was expedited by 20,000 line miles of private aeromagnetic flights over areas having sparse outcrops. Five aeromagnetic map sheets covering areas in the eastern townships of Quebec were published by the Canadian Geological Survey. The Quebec Dept. of Mines tested water and soil samples for trace metal indications of mineralization in a 50-sq mile area in the Lemieux township lead-zinc area, Gaspé Peninsula. Results suggest that geochemical methods could aid prospecting in this area of thick vegetation and poor rock exposure.

NOVA SCOTIA—During 1953, most of the northern third of the province, and large areas in the southwestern part were covered by aerial magnetic and radioactivity surveys. Gravimeter surveys for salt were made in part of Hants County and in northern Cumberland County, and ground geophysical studies were carried out in the zinc-lead-copper district of Richmond County.

An aeromagnetic survey of more than 7500 line miles was successfully completed at Waboden, Manitoba, despite temperatures as low as −32°F, and frequent magnetic storms, some causing variations up to 300 gammas in a few minutes.

BRITISH COLUMBIA—Geochemical surveys now generally involve collection of samples of one or more of the following classes: natural waters, soils, or plants. A method of detecting as little as one part of copper or zinc in one thousand million of natural waters has been developed by R. E. Delavault. Anomalous concentration of copper or zinc in stream waters and soil samples has been shown to indicate mineralization. Selective concentration of nickel, cobalt, silver, zinc, manganese, and molybdenum by certain common native trees appears to be a useful indicator of possible mineralization, even in areas covered by as much as 30 ft of drift. Nickel anomalies may be particularly useful to supplement geophysical data. Where copper ores also contain molybdenum, the molybdenum content of balsam trees has been found to be a sensitive indicator of mineralization. Zinc content of glacial drift is proving to be of particular value in discovering mineralization. Aerial magnetometer surveys were made in two areas of the Peace River district, northeast British Columbia, and in the Cranbrook-Kimberley area in the southeastern part of the province. A dip-needle survey was conducted in the McDame Lake area to assist in outlining a serpentine body.

Combination airborne magnetometer and radioactivity surveys covered an area of about 20,000 sq miles in central Newfoundland.

ALASKA—An aeromagnetic survey showed new anomalies in a nickel area in Alaska, and a few small magnetic and geochemical projects are in progress. During the past 4 years the USGS has been conducting permafrost investigations in northern Alaska, taking advantage of the drilling program in Naval Petroleum Reserve No. 4. Tens of thousands of thermistor readings at drill hole installations relate temperature to lithology, surface conditions, and topography. During the past year emphasis has been on determination of thermal constants of material in the permafrost and active layers. A seismological station has been installed on St. Paul Island in the Aleutians. This is one part of a projected seismological triangle to include a station already operating on Adak and one to be set up at Unalaska. The stations will be used in monitoring seismic activity related to volcanoes along the Aleutian arc.

Europe and the Near East

ICELAND—A regional gravity survey was completed by the University of Iceland, and a regional magnetic survey has been started by the National Research Council. Electrical resistivity and related methods were used for prospecting for natural hot water by the State Electrical Authority.

FINLAND—Magnetic and electrical methods were used for limestone, asbestos, feldspar, and pegmatite minerals. Seismic and electrical methods were used for testing sites for waterpower stations, harbor constructions, and irrigation dams. A study of the occurrence of copper, zinc, nickel, and molybdenum in ground water and in plants suggests that geochemical methods can complement other geophysical surveys by indicating the metals giving anomalies.

FRANCE—The Compagnie Générale de Géophysique, Paris, surveyed for iron ore in Normandy and sulphur in Sicily. Seismic methods were used to follow the eastern extension of the Lorraine basin. Several dam sites were surveyed by electrical and seismic methods, in southeast France and in Guinea, West Africa.

GERMANY—Seismic methods have been used in a variety of ways by the Institut für angewandte Geophysik, Germany. Refraction methods determined glacier thickness in the eastern Alps, in conjunction with investigations of the elastic behavior of the ice. In another area, reflections from basement horizons at depths of 1040 meters, 20 km, and 28 km, are interpreted as caused by the upper boundaries of granite, basic, and ultrabasic rocks, respectively. Seismic methods are reported used by the University of Munchen, to determine thickness of Pleistocene sediments in the northern foreland of the Alps, to determine ground-water-bearing zones in the sediments, and to locate boreholes for exploring underlying strata for coal.

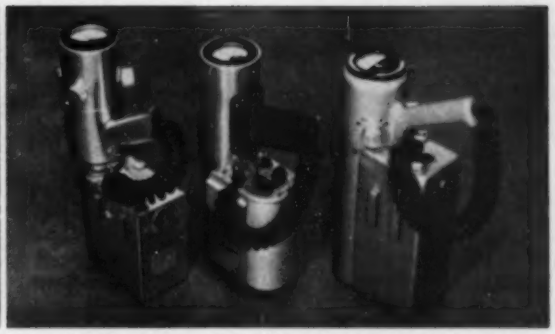
ITALY—Work on the national gravimetric net was continued. Carlo Morelli of the Geophysical Institute of Trieste began a marine survey in the northern half of the Adriatic Sea, with an underwater gravimeter. Successful electrical surveys for locating steam well sites were made by the Compagnie Générale de Géophysique in the Larderello region. Artesian water was found near Catania, Sicily. A geophysical survey in search of pyrites was conducted by a mining company in Cyprus.

TURKEY—Resistivity equipment has been acquired by the General Directorate of Highways, and a resistivity survey is under way to obtain subsurface information for use in designing highway tunnels. Refraction seismic equipment is also being purchased.

An extensive study of water resources was made by geophysical methods in Afghanistan.

Asia and Australia

JAPAN—An off-shore seismic refraction survey produced good results in the Ube coal field, and three other seismic surveys for coal were made. Both reflec-



PHYSICS AND BOTANY in the uranium search.—Plant at left was tested during prospecting studies in New Mexico, see p. 217. Small scintillation counters developed by USGS and AEC use high counting rate of sodium iodide crystals.

tion and refraction methods were used to work out complex geology in the Hichiku Plain, Kyushu. Seismic, spontaneous polarization, and resistivity methods disclosed a pyrite orebody in Oita Prefecture.

Private mining companies in Japan have made several discoveries: a pyrite deposit in Okagama Prefecture, by resistivity and spontaneous-potential methods; a copper orebody in Wakayama Prefecture, and a lead-zinc deposit in Hokkaido, both by the spontaneous-potential method. A number of electrical and magnetic surveys have been made for iron, tungsten, and sulphide deposits at various mines in the Tohoku, Chubu, and Tyugoku regions. Geochemical methods were used in several copper and pyrite mining areas. Refraction seismic and resistivity methods were used to make more than 120 surveys for ground-water. Regional surveys by electrical methods were conducted for underground water in the central and western parts of Honshu.

The Japanese Geological Survey and Kyoto University studied the changes of the gravitational field with time, and the relation to ground subsidence and seismic activity near Kyoto and Osaka. Gravity, magnetic, electrical, radioactivity, and geochemical surveys were made at the new Usu volcanic area, Hokkaido, to determine the source of geothermal energy for power. Electrical methods were used for a similar purpose in the Kirishima volcanic area, Kyushu.

INDIA—Self-potential and magnetic methods were used in three areas by the Geological Survey of India. Several self-potential anomalies were found in the Singhbhum copper belt in Bihar State, at Goni in Madras State, and at Chitaldrug, Mysore State. Two magnetic surveys for magnetite-bearing manganese ore were made in Madhya Pradesh State. Test pits on some of the anomalies revealed manganese ore bodies at depths of 20 to 60 ft. Seismic reflection surveys in the Gangetic alluvium near Calcutta revealed the thickness of the alluvium.

The Central Water and Power Commission of India obtained valuable subsurface information at dam sites by the use of refraction seismic and resistivity methods. A private company is conducting seismic, gravity, and aeromagnetic surveys in an alluvium tract of the Brahmaputra River.

In an area in Madras State, India, positive self-potential anomalies of 20 millivolts were found to be characteristic of the interface between thin saturated surficial sand and underlying shale. An additional potential difference of 30 millivolts was found to be characteristic of areas where appreciable underflow in arroyo channels existed, due to electrofiltration potentials. Self-potential contours agreed closely with the drainage pattern and are interpreted as being due to increased sand thicknesses along drainage lines.

The Geological Survey of the Federation of Malaya used geophysical methods to determine thicknesses of alluvium and weathered rock.

AUSTRALIA—As a result of airborne radioactivity surveys, anomalies were found in a 200-mile belt from Darwin to Katherine. More than 50 separate uranium discoveries by ground parties have resulted from indications given by airborne radioactivity reconnaissance. The Australian Government is sponsoring extensive geochemical explorations. In one method of analysis, soil samples taken systematically on a grid pattern are tested with an organic reagent which indicates semiquantitatively the presence of copper, lead, or zinc. Two lead deposits were discovered by such analysis of residual soil at Mt. Isa, Queensland.

Africa

SOUTH AFRICA—Radioactivity bore-hole logging in auriferous beds of the Witwatersrand system has been employed by a special unit of the South African Geological Survey, particularly in the Klerksdorp and Orange Free State areas. General consistency has been established within this region, and auriferous reefs of economic significance have given radioactivity curves that differ conspicuously from those given by conglomerates poor in gold.

UGANDA—The Geological Survey of Uganda has used gravimeter surveys to determine depths of soils, resistivity surveys have been used for ground-water studies, and experimental magnetometer and gravimeter studies were carried out. Geochemical prospecting is planned. The Public Works Dept. uses resistivity methods to solve ground-water problems.

RHODESIA—Gradiometer surveys were made across the Great Dyke and in the Selukwe area, Southern Rhodesia. Experimental surveys were conducted to determine the best methods of exploration for copper, and resistivity surveys are being continued successfully for ground-water supplies in Southern Rhodesia. Private studies for ground water and for the selection of a dam site was conducted in Swaziland. Magnetometer surveys were conducted in the Ijolite area to determine the subsurface form and extent of an intrusive mass, and in another area to determine the pattern of metamorphic rocks below a laterite cover.

A copper orebody was discovered as the result of a resistivity survey near Kettara, French Morocco, by the Compagnie Général de Géophysique. Refraction seismic studies were made in the Sahara Desert.

Latin America and Caribbean

The Geophysical Section of the Instituto Geológico del Peru conducted investigations for ground water, using resistivity and refraction seismic methods. Resistivity surveys for ground water on the Leeward Islands, B. W. I., were conducted by the office of the Government Geologist. An airborne radioactivity and a magnetometer survey for iron ore were made in Jamaica. Recordings of broad-band seismic records were made in an attempt to improve interpretation of records in difficult areas of Trinidad.

This review summarizes published items of the past year, augmented by data contributed by about 75 correspondents representing government agencies on every continent, universities, oil and mining companies, and geophysical exploration companies. Thanks are due to Zane E. Spiegel, University of Utah, who abstracted and compiled a large part of the information, and to the correspondents.

Nonmetallic Mineral Production Up in 1953

PRODUCTION of nonmetallic mineral raw materials used by the fertilizer, ceramic, chemical, and construction industries and many others, was greater during 1953 than in any previous year. Production of fertilizer minerals was the highest in history despite somewhat decreased consumption in the second half of the year. Marketable phosphate rock production increased 10 pct to an estimated total of 13.1 million LT, valued at $78.5 million, and potash production was estimated at 1.8 million tons of K_2O equivalent, valued at over $60 million.

Crude gypsum output exceeded the 1952 total and approached the record of 8.66 million tons mined in 1951, with indications that 1953 will show a new all-time high. Gains and losses among gypsum products were irregular, with major gains in plate-glass and terra-cotta plasters, sanded building plasters and miscellaneous building plasters, and principal declines in base-coat plasters, prepared finishes and tile. Lath and wallboard outputs were each about 20 pct higher than in 1952.

Although new asbestos production in Canada improved the overall picture, strategic grades were still tight. Research continued on the synthesis and treatment of asbestos and the development of substitutes. Several exploration projects in search of domestic deposits of asbestos were under way.

Production and consumption of barite will establish a new record largely because of high activity in oil well drilling. Meanwhile, continuing heavy demand for tetraethyl lead in gasoline and anti-knock compound held bromine production at a record level.

New chlorine capacity was largely responsible for a record production of salt in 1953.

Commodity Listings

ASBESTOS—During 1953 many asbestos companies carried on significant operations. Conda Properties is to begin open pit mining at an asbetos deposit near Victorville, San Bernardino County, Calif. In Arizona, the American Asbestos Co. has found a workable orebody near Globe, and the Sorenson & Williams Mining Co. has begun work on an outcrop in the Salt River district of the San Carlos Indian Reservation. The Canadian Johns-Manville Co. has bought a new asbestos deposit in Reeves township, Ontario, in the same general area as the Munro mine. However, no plans have been made to establish production facilities. The new mill of Dominion Asbestos Mines has been treating about 1100 tons of ore a day, and it is expected that this will be increased shortly to 2200 tpd. The company made its first major shipment of asbestos fiber in September. Western Asbestos & Development, Ltd. began drilling of the Sproat Mountain chrysotile property near Revelstoke this year. The chrysotile is similar to that at Asbestos and Thetford Mines, P. Q. As a result of new equipment, good results obtained from spinning tests, and substantial ore reserves, Cassiar Asbestos Co. in the McDame Lake area, British Columbia, expects to be producing 500 tpd by the fall of 1954.

The National Bureau of Standards has developed simple chemical procedures to reclaim asbestos material discarded during repair and refitting of ships by the U. S. Navy Bureau of Ships. The recovered asbestos is not chemically changed and may be used as electrical and heat insulation, asbestos paper, and as filler in molded plastic compounds.

The Defense Minerals Exploration Administration has given support to several exploration contracts in Arizona and California during the year.

Asbestos properties in the Tinaguillo area of Venezuela were acquired in August 1953 by Amianto Venezuela Compania S. A. (known more generally as AMVECO) of Caracas. Two properties, the El Tigre and the Montanita, about 3½ miles apart are being mined. The mill, which is at the El Tigre mine, has operated in a small way for some years, but production had increased considerably by the end of 1953.

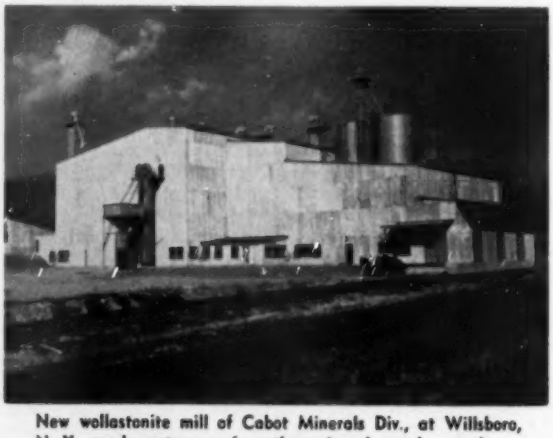
BARITES—The change in the use pattern for barites has recently been underlined by the announcement in 1953 by the DuPont Co. of the discontinuance of the manufacture of lithopone. The great improvements in titanium pigments have steadily pushed lithopone into a position of lesser importance. At the same time production of ground barites for oil well drilling mud has held or increased its dominant position. For example, 1953 production at Walton, Nova Scotia, was greatly increased over its former peak year.

BERYL—Production of beryl proceeded at an accelerated rate under the impetus of the Government buying program for these strategic minerals. The purchasing depot at Custer, S. Dak., received considerable quantities of beryl from numerous sources.

The Bland Mining Co. is the largest producer of beryl from its rich strike south of Custer. The company is concentrating tantalite-columbite.

No new major producer came in during 1953, but much is being done to recover beryl from pegmatites being treated for feldspar and spodumene. The USBM has programs at Tuscaloosa, Ala., and Rapid City, S. Dak.

BUILDING STONE—Indiana occupies the leading role in building stone production in the U. S. More than 50 pct of the total building stone production of the U. S.



New wollastonite mill of Cabot Minerals Div., at Willsboro, N. Y., marks entrance of another mineral, another producer, into nonmetallics field.

comes from Lawrence, Monroe, and Owen counties, and Indiana produces more than 70 pct of all the building limestone produced in this country.

CALCAREOUS MARL—Calcareous marl is produced in small amounts in Indiana and is used primarily for agricultural lime. Production of marl in Indiana seems to be on the decline.

CLAY & SHALE—Because of the large development of ceramic industries in Indiana, the clay and shale that constitute the principal raw materials are vastly more important to the economy of the state than would be indicated by a raw material value listing. Interest is developing in the possible use of some Indiana clays and shales for light-weight aggregates, but to date none have been made from Indiana raw materials.

CEMENT—The cement industry in the U. S. and Canada continued the expansion and modernization which started after World War II. By building new plants and increasing the capacities of existing factories the industry has raised its productive potential more during the last 7 years than in the preceding 25-year period.

Total obtainable production of the industry reached approximately 215 million bbl in 1942. It has now grown to between 260 and 280 million bbl per year. Actual production in the U. S. in 1952 reached 249,256,154 bbl and during the 12 months ending Sept. 30, 1953, the total production was 263,605,000 bbl.

Individual cases of expansion and modernization which have been mentioned during 1953 in the technical press include:

- Lone Star Cement Corp. installed an additional kiln in its new dry process plant at Maryneal, Texas.
- The Dragon Cement Co. installed new crushers, impactors, air separators, ball mills, and storage and blending facilities at Northampton, Pa. The same company also installed additional grinding equipment at its other plant at Thomaston, Maine.
- Additional equipment installed by Lone Star Cement Corp. at Roanoke, Va., increased the capacities of that plant by 50 pct.
- At Kingsport, Tenn., the Penn-Dixie Cement Corp. added a 90x 300-ft raw materials storage.
- The General Portland Cement Co. authorized the expenditure of $4 million to cover completion of an addition to its Tampa plant and to start construction at Houston, Texas, to increase the capacities of that plant by 1.25 million bbl per year.
- Huron-Portland Cement Co. authorized a $100,000 expansion of its distribution plant at Toledo, Ohio.
- At Victorville, Calif., the Southwestern Portland Cement Co. installed a new 10½ x 300-ft kiln and additional equipment to double the capacity of the plant. At the same plant the company installed completely new facilities at the quarry.
- The Marquette Cement Manufacturing Co. authorized $3 million for the purchase of an additional kiln and related equipment for Cape Girardeau, Mo., plant.
- At Humboldt, Kan., the Monarch Cement Co. spent $750,000 on a new shale crushing and drying plant.
- The Oregon Portland Cement Co. spent $1 million on an expansion program including modernization of the kiln firing system and increased stone conveying and crushing capacities.
- The Universal Atlas Cement Co. erected new buildings for coal mill, raw mill, firing department, and finish mills at its Universal, Pa., plant.
- Finally, the Dewey Portland Cement Co. at Davenport, Iowa, added eight 144-ft cement storage silos.
- A new concern, Old Dominion Cement Co., received a certificate of necessity from the Defense Production Administration for purchase of steel for a new cement plant at Pennington Gap, Va.
- At Villeneuve, P. Q., another new firm, the St. Lawrence Cement Co., commenced construction of an $11 million cement plant.

At present approximately 60 pct of American cement plants use the wet process. This trend has, however,

URANIUM FROM PHOSPHATE

The Atomic Energy Commission is interested in uranium occurring in certain marine sediments, particularly the phosphorites and black shales. Formations are low grade, extraction problems are formidable—reserves are large.

1 **Highest uranium concentration occurs in phosphate deposits of the Pliocene Bone Valley formation in Florida, and the Permidan Phosphoria area of Wyoming, Montana, Idaho, and Utah. Although concentration amounts to only 0.2 to 0.4 lb of U_3O_8 per ton of phosphate rock, the AEC has actively sponsored basic research and process development in cooperation with the phosphate and fertilizer industry. The objective is production of uranium concentrate byproduct from fertilizer and chemical operations.**

2 **The AEC phosphate program encompasses all opportunities for recovery of uranium at acceptable prices. Commercial phosphate rock and phosphate pebble have been utilized as a source of uranium since production began at a private plant, September 1952.**

3 **Development of feasible process technology to cover all available low grade materials will continue to cause furrowed brows for some time. Process studies include recovery of byproduct uranium from industrial sources such as:**

1—Wet Process phosphoric acid
2—Phosphate chemicals
3—Triple phosphate fertilizers
4—Nitric phosphate fertilizers
5—Normal superphosphate fertilizers
6—Electric furnace operations for elemental phosphorous

4 **First production plant to recover uranium from phosphoric acid is now under construction by the Blockson Chemical Co. at Joliet, Ill., and General Chemical Div., Allied Chemical & Dye Corp., is in the pilot plant stage. In the fertilizer field, U. S. Phosphoric Products Div., Tennessee Corp., is piloting a feasible process to compare uranium recovery and economics of production.**

5 **Mathiewson Chemical Corp. and Armour Fertilizer Works are in various stages of research to determine design and cost of a plant for uranium recovery. New plants for wet process acid have been announced by International Minerals & Chemical Corp. and Virginia-Carolina Chemical Corp.**

Economic utilization of the vast U. S. phosphate reserves is complicated by the interlocking byproduct recovery picture. Tremendous amount of raw material exist, carrying minute percentages of recoverable fluorine, alumina, and vanadium in addition to uranium—and of course phosphate for fertilizer. Present research work pressed by the urgency of the Atomic Energy Program may incidentally help unlock this whole group of vitally strategic materials.

recently been reversed; many new plants have adopted the dry method. More satisfactory fuel economy is attainable, and modern proportioning, blending, aerating, and fluidizing equipment makes it possible to obtain a completely satisfactory degree of uniformity with the dry process. Among new technical developments which will contribute to this trend is the so-called Suspension Preheater, invented in Germany, and now being installed for the first time in this country in a plant in eastern Pennsylvania. A development used in the wet process is the centrifugal classifier for slurry.

A striking recent development that continued during 1953 was the use of longer and longer rotary kilns, particularly for the dry process. This contributes to fuel economy and increased overall production with a reduction in plant overhead and labor.

COLUMBIUM AND TANTALUM—Demands for high temperature alloys have stimulated search for domestic deposit, but no important occurrences have been found. Some small production as a byproduct of spodumene mining in North Carolina.

CRUSHED STONE—The trend of the crushed stone industry, during the past few years, has been toward fewer quarries which are, however, better equipped and have considerably larger productive capacity. The total production of crushed stone has risen steadily. Most of the crushed stone produced is used for aggregates but some producers are beginning to consider the industrial aspects to which their products may be suited. Very few crushed stone producers in Indiana supply raw materials for industrial purposes.

FELDSPAR—International Minerals & Chemical Corp. is expanding feldspar operations. Three new plants are planned, and present equipment is being enlarged and modernized.

In southern Connecticut, where IMC holds large reserves of feldspar ore, diamond drilling has been completed and plans are being drawn for a plant. It will probably employ the LeBaron-Lawver dry beneficiation process, resulting in substantially lower production costs.

Diamond drilling is also under way at IMC's nepheline syenite deposits in southern Ontario. It is expected that a new mill for processing nepheline syenite will be built at Blue Mountain, Ont., and should be in operation by mid-1954.

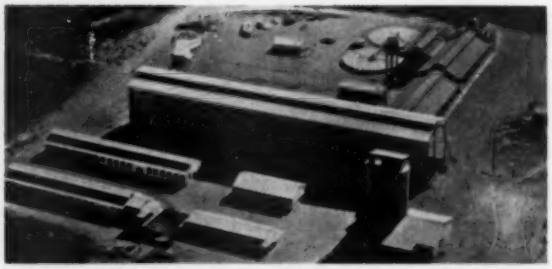
International Minerals & Chemical Co. is enlarging present equipment in the meantime. Flotation capacity at Spruce Pine, N. Car. has been increased by 50 pct. New facilities for fine grinding have been installed at Erwin, Tenn. The main laboratory of quality control at Kona, N. Car. has been revamped and expanded.

Feldspar production in 1953 was expected to remain about the same as in 1952, with somewhat higher prices being received for ground material. The trend of recent years towards recovery of greater proportion of the total feldspar supply from flotation processes continued.

The State Geological Survey of Kansas has devised a method for recovery of feldspar from river sands. The remaining sand can be purified for commercial use. Some Kansas river sands contain as much as 30 pct feldspar.

FLUORSPAR—Supplies were ample throughout 1953, contrasting with previous years. Estimated production in 1953 will be about 325,000 tons of all grades of finished fluorspar. This was short of the 1952 statistics by 25,000 tons. Decline was probably due to decrease in metallurgical-grade material and increased competition from foreign fluorspar. A new record was established in consumption. Steelmaking, fluorine chemicals, ceramics and a variety of uses consumed an estimated 600,000 tons.

An important factor in the fluorspar outlook is research underway on a commercial process to recover fluorine from phosphate rock. Large quantities of fluorine are available from this source.



Cement review lists wide range of plant expansion and modernization. Postwar growth in cement production has been world wide, with construction of many modern plants such as this one of Cementos del Caribe, S.A., located on the Magdelena River in Colombia.

The 1952 use was 521,500 tons, and the majority of the increase in 1953 was attributable to the rise in the fluorine chemical industry. Significant plant developments are:

- New 300-ton flotation plant of the St. Lawrence Fluorspar Co. at Wilmington, Del. Supply for mill will come largely from the company's mine in Newfoundland.
- U. S. Steel Corp. began operation of a new Heavy-Media and flotation plant at Mexico, Ky.
- Minerva Oil Co. completed a flotation mill annex at its Illinois plant to convert a portion of available ore to acid or ceramic grade fluorspar and to recover previously wasted fines.
- The Simplot fluorspar mill at Meyers Cove, Idaho, was destroyed by fire in early spring.

Two large bodies of fluorspar ore with recoverable zinc and lead values were discovered in the Cave-in-Rock district, Hardin County, Ill. Drilling was completed by DMEA and Ozark-Mahoning Co. on the Hill-Ledford tract in January 1953. Fluorspar removed from list of minerals for DMEA exploration in April.

There was a considerable flourish of activity in Mexico as a source of fluorspar. Larger reserves and construction of a new mill increased Mexico's potential as a supplier.

GARNET—There has been much interest in and work done on finding markets for byproduct garnet occurring as an accessory mineral in many ores. So far as known none of these byproduct garnets have the combination of desirable properties—hardness, toughness, range of grain size, and incipient fracture—inherent in the garnet produced near North River, Warren County, N. Y. For various reasons none of these garnets have been found acceptable for the major established uses for garnet. Wholly new, large scale, tonnage uses for low priced garnet have not yet been found.

GERMANIUM—A great amount of interest due to development of transistor technology. Surveys of occurrence in coals, peat, etc. have yielded many new and interesting data, but no commercial applications have yet been made. Eagle-Picher Co. remains as major producer with byproduct from lead operations.

GRAVEL AND SAND—The production of gravel and sand in Indiana has maintained a steady pace during 1953. An intensive investigation of high-silica sand resources was made with the goal that some sands in Indiana may have a potential value in glass manufacturing and other purposes that require a pure grade of silica sand. The results have been encouraging. Many deposits, in their raw state, fall within the ranges of purity and grain size that characterize the major high-silica sand deposits of the U. S. Whether they can be used commercially depends upon the development of methods of washing and beneficiation.

KAOLIN—Georgia kaolin production held at a high level in 1953. Numerous plant expansions were announced among which were a large new spray drying unit for Edgar Brothers Co. at McIntyre, Ga., and a new water washing unit for United Clay Mines plant

Carlsbad potash production set all-time high. Shown is part of Southwest Potash Corp.'s new plant in Carlsbad, N. Mex. Flowsheet uses closed circuit wet grinding, flotation, centrifuging, washing, and thickening. A heavy duty Dorr Hydroseparator is shown.

at Sandersville, Ga., (previously producing only air-float clay.) Calcined clay, made by only a few producers, has been increasing in interest and it is reported that several new calcining furnaces have been or are being added to present production capacity. Continuous progress has been made in the production of kaolin or ultra-fine particle size by the use of super-centrifuges. Kaolin is now regularly produced 90 pct finer than 2 microns from which most of the ¼ micron particles have been removed. The removal of the ¼ micron particles, largely bentonitic, reduces the viscosity and markedly increases the brightness.

INDUSTRIAL DIAMONDS—Considerable activity has been shown throughout the year for alternate grinding methods which would reduce the use of industrial diamonds. Now being used on experimental production basis are the electrolytic, ultrasonic, electroarcing, and silicon carbide grinding methods. There has been an upward trend in diamond salvage and reuse, approaching 1.0 million karats per year.

Manufacturers of diamond abrasives are finding methods of better adaption of a wheel to the job it is doing, for improvement of wheel life. USBM study of diamond orientation in drill bits is showing methods of improving bit life by several hundred percent.

E. P. Pfleider, University of Minnesota, also has been conducting tests on the problem of diamond orientation.

LIME—Production figures for the first 7 months of 1953 show an increase of about 16 pct over the corresponding period of 1952, but the gain is over-emphasized by the fact that the steel strike occurred during the 1952 period. It is probable that the gain for the entire year was considerably less than 16 pct, but nevertheless was substantial. Statistics for the first 7 months of 1953 indicate a decline in agricultural and building uses, but chemical, industrial, and refractory uses increased.

Continuing progress is being made in the technique of lime manufacture. A useful formula has been developed for determining the proper flow of limestone through a rotary kiln. Much study was devoted in 1953 to the theory and practice of lime manufacture. New equipment has been introduced at several plants to increase plant efficiency and improve the product.

LITHIUM—1953 saw a large expansion in the productive capacity of the lithium industry. Foote Minerals Co.'s new refining plant at Sunbright, Va., went into operation in August 1953, and the mine and mill at Kings Mountain, N. Car. were expanded to meet increasing demands, a total expenditure of $3 million. Imports of lithium ores from Southwest Africa, Rhodesia, and Mozambique increased, and late in 1953 American Potash & Chemical Co. announced a joint development with Selection Trust Ltd. of large deposits in Rhodesia. Lithium Corp. at Minneapolis likewise increased its production in 1953 using spodumene from both South Dakota and North Carolina. The lithium mill at Tinton, S. Dak., burned on Nov. 27, 1953.

The U. S. Geological Survey is carrying on nationwide studies of the geology and resources of beryllium, lithium, kyanite, silica, talc, titanium, and columbium.

American Potash Co. first offered lithium carbonate on the market, January 1953. Black Hills Tin Co. constructed a new spodumene mill in South Dakota. Quebec Lithium Corp. is developing a spodumene deposit at Val d'Or, P. Q. It is reported that the orebody contains at least 2 million tons of 1.2 to 1.3 pct Li_2 ore.

Nichols Chemical Co. is reported to be constructing a lithium chemical plant at Canon City, Colo.

MICA—Increases were reported in 1953 for muscovite block, film, and splittings; domestic production of muscovite block mica; and sales of ground mica, compared with 1952 figures. The Government purchasing program for strategic mica was extended until June 30, 1957 and the purchase of nonruby mica was authorized. DMEA reduced the Government's financial participation in approved exploration projects for muscovite block and film from 90 to 75 pct, effective in November. Synthetic mica developed by the USBM at its Electrotechnical Laboratory, Norris, Tenn., was found to have properties and uses not possessed by natural mica. New potential uses included glass-bonded mica ceramics, phosphate-bonded and hot-pressed ceramic dielectrics, and as a bonding agent in abrasive wheels.

The Spruce Pine district, North Carolina, is now producing about 60,000 tons annually of dry-ground mica. The mica sales from this district are more than $2 million a year. The demand for dry-ground mica has been increasing since the middle of February.

Green sheet mica is also accepted now at the Government Mica Purchasing Depot at Spruce Pine. It must meet the regular ruby mica specifications and also be tested by the Q-meter. Prices probably average about 20 pct less than for ruby mica.

Several Georgia mines worked during World War II have been reopened. High grade ruby mica has been reported from some deposits. The mica is shipped to Spruce Pine.

Ten mica mines were operated in New Hampshire. Only one had been in operation before the recent opening of the Government purchasing depot.

The General Electric Co. is now producing an integrated mica sheet called the Mica Mat. It is composed of flakes about 1/20 in. across and about 1/20,000 in. thick, and it can be made from muscovite in any form. The sheet is used in the manufacture of insulation.

Early 1953, Samica Corp., Rutland, Vt., started producing sheet mica made from scrap. This production of sheet is largely confined to fabricators scrap, but investigations are underway for use of natural scrap.

MONAZITE—There are a number of DMEA sponsored exploration programs and several properties in Idaho and North Carolina are producing.

PEAT—A small amount of peat is produced in Indiana and is used mainly as a mulch in nurseries. Production of peat also seems to be on the decline.

POTASH—Carlsbad potash production set a new all-time high. Marked change occurred in the market conditions this year; it changed from seller to buyer. Five mines in the Permian Basin operated at a rate of over 25,000 tpd. Production in 1953 will exceed 8 million tons. During the first 9 months 2.45 million tons of potash salts were consumed containing 1.42 million tons of K_2O. This was an increase of 10 pct in salts and 11 pct K_2O. This included domestic and imported salts.

According to C. F. Coope, "As I see the picture for 1954, I do not think we should be too discouraged."

SILICA—Refractory manufacturers are now making a low-alumina, silica brick and are washing the quartzite after crushing to insure purity. They are departing from the time-honored quartzite (ganister) as a raw material and utilizing quartz conglomerate, as washed pebbles are very pure. About 10 to 15 pct of sales in this field are to glass melting works, the remainder going to the steel industry.

The silica industry is very much aware of the benefits of percentage depletion allowance granted by the

Government on gross income. This was developed to increase incentive for prospecting and exploration. Some confusion now exists because only a 5 pct depletion is allowed on sand and sandstone, whereas 15 pct is allowed on quartz.

PHOSPHATE ROCK—Full production was maintained all year with marketable phosphate rock production estimated to be 12.4 million LT of rock containing 3.9 million LT of P_2O_5. Market changed markedly from a sellers' to a buyers' market.

Numerous expansion programs were completed or were nearing completion. Other planned expansions temporarily were stopped to see what the market does. Drought and lower farm income have been reflected in decreased demand for phosphate rock.

SULPHUR—Mexican Gulf Sulphur Co. was reported in production. Hot water has been pumped into the brimstone. Pan-American Sulphur Co. is developing a Frasch process mine in Mexico, which is reported to have more potential reserves than Mexican Gulf Sulphur's operation. Garden Bay Mine operated by Freeport Sulphur Co. in Louisiana is producing sulphur.

In the non-Frasch sulphur producers, the Leviathan mine in California is shipping brimstone from a shallow deposit to Anaconda's Yerrington, Nev., plant for sulphuric acid production. The brimstone is not concentrated, but burned directly to produce SO_2.

Brown Paper Co., Berlin, N. H., is using FluoSolids technique for production of sulphur from pyrites. Vermont Copper Co. at South Stratford is supplying the raw materials.

Sulphur has not been heavy on the market this year and production from some of the long-established mines was down in the second half. A price increase for sulphur was awarded during the year.

In the foreign market, Italy has built up a considerable stock pile of elemental sulphur because the world market price is not right for the high cost material produced there. Generally, the world production of sulphur seemed to be well balanced during 1953.

TALC—Sierra Talc and Clay Co. has moved its operating plant from Los Angeles to Olancha, Calif., 7 miles from its clay mine. Southern California Minerals Co. continued mining operations at the Treasure deposit of talc near Dillon, Mont., during 1953, and it has a 20-acre mill site and complete ore washing plant in operation at Barratts, Mont. Sierra continued to mine talc for grinding from its Montana property.

Important activities have been carried on during 1953 to advance substitute material for block steatite talc. The most promising materials were phosphate-bonded ground talc, phosphate-bonded synthetic mica, and hot-pressed synthetic mica. If these tests prove successful, dependence on Italy and India for natural block steatite will be largely eliminated.

TITANIUM MINERALS—During 1953 a continuing high level of interest and activity was shown in most phases of the titanium industry. Several new developments in mineralogy and chemistry will probably be important in future exploration and development of titaniferous deposits. The existence of a separate mineral species *arizonite* has been seriously questioned, as recent work indicates that the so-called arizonite sands carrying 55 to 70 pct TiO_2, consist largely of impure mixtures of hematite, ilmenite, anatase, and rutile. These aggregates, produced by the weathering of ilmenite, result from the oxidation of the iron in ilmenite, and the conversion of some of the titanium to rutile or anatase. Similarly, leucoxene, is probably not a separate mineral, but instead a titanium-bearing alteration product consisting of fine-grained rutile or anatase, or mixtures of these with hydrous or anhydrous amorphous material. Of potential use to those prospecting for titanium is a quantitative field test for titanium, that was described in the June-July, 1953 issue of *Economic Geology*, and was developed by two USGS chemists, W. W. Brannock and Leonard Shapiro. The USGS also undertook study of the rutile deposit at Magnet Cove, Ark., where important amounts of niobium (columbium) are found associated with the rutile.

The principal development in mining was the announcement by Du Pont in September that construction would soon start on a new mine and plant, near Lawtey, Fla. This operation, to be known as the Highland plant, will be 17 miles north of, and similar to Du Pont's Trail Ridge plant near Starke. Exploration was also reported on the titaniferous magnetite deposit at Iron Mountain, Albanay County, Wyo., and on a perovskite deposit in the Iron Hill district of Gunnison County, Colo.

Although considerable interest was shown in certain titanium-rich soils of Hawaii, the fine-grained nature of the titaniferous portions makes commercial development unlikely.

In Finland, development of the Otanmaki titaniferous magnetite deposit was still under way, and production was slated to begin in late 1953, or early 1954.

Although a shipment of ilmenite concentrates was made in February 1953 from sands of the Ranagiri District, Bombay State, India, it has not been conclusively demonstrated that the sands are commercially important. A titanium pigment plant in India was operated for only a few months in 1952, and might be reopened if the import of titanium dioxide is banned by the Government of India.

A plant to recover ilmenite, rutile, and zircon from beach sands of Natal, South Africa, was to be completed in the latter part of 1953; first shipments of concentrates will be to Europe.

Sands of Western Australia are arousing considerable interest because they do not contain chromium as do those in the eastern part of the country.

WOLLASTONITE—The new Cabot wollastonite mill at Willsboro, N. Y., plans for which were described a year ago, was completed in September. After the usual tuning up period mill performance was even better than anticipated, both in volume of production and in quality and uniformity. The air tables have not yet been installed, because it was found that clean separations could be made without them by the use of double splitters on the Exolon magnetic separators. Unless an unexpected change in ore composition occurs the air tabling step may never be necessary. As anticipated, research and sales progress indicate that chief markets will be in the paint and ceramic industries. In both industries wollastonite has shown outstanding and unique properties.

Examination of numerous reported wollastonite deposits and many ore samples has failed to turn up other deposits at all similar to that at Willsboro. The Willsboro material is characterized by unusually brilliant whiteness, very pronounced fibrous cleavage, and freedom from carbonates or other impurities in the finished products. No other wollastonites so far examined have had any one of these properties. This illustrates once more that many industrial minerals, properly known by the same mineral names, are often so far different in physical properties that their use patterns may be quite far apart.

It is reported that plans are maturing for the development of wollastonite deposits north of Blythe, Calif.

ZIRCON—The supply of zircon during the year was sufficient to meet all demands, even though increased activity was reported in production of the pure zirconium metal. Zircon is extracted from sands as a by-product of mining for ilmenite and rutile and is produced largely from sand in Florida, and along the east coast of Australia.

Carborundum Company completed and put into operation a plant at Akron, N. Y., to supply zirconium metal to the AEC. The plant is rated at 150,000 lb per year output.

The Editors of *Mining Engineering* wish to thank the officers and members of the Industrial Minerals Div., and the personnel of the USBM who supplied information for this review.

Annual Review

Mineral Industry Health and Safety

by S. H. Ash

SAFETY records have improved in all branches of the mineral industry. While annual production was rising from $2 billion in 1910 to nearly $12 billion in 1950, fatalities decreased from 3539 in 1911 to 974 in 1951. And, although safety progressed under hand methods, it progresses more effectively under modern, mechanized methods. But powered devices such as electric or diesel units can in themselves create new hazards unless proper safeguards are instituted.

Health

Use of diesels underground is increasing. Diesel equipment has been used in construction of 34 tunnels in 16 states in the last 17 years. The 77 noncoal underground mines in 24 states using diesels underground range from mines with large open stopes to those with narrow veins, so that the ventilating problems represent a good cross-section of U. S. mining. The U. S. Bureau of Mines has received no report that anyone has suffered ill effects from the proper use of properly maintained equipment. The necessity for correct maintenance and use of satisfactory exhaust conditioners cannot be emphasized too strongly.

In the relatively few years that have elapsed since the causes of pneumoconiosis (silicosis or *miners consumption*) have become more fully understood and more widely recognized by society, tremendous strides have been made in its prevention.

Increasing importance of uranium production has prompted consideration of possible health hazards in mining uranium ores. Preliminary studies in the Colorado Plateau region by the Bureau of Mines and the U. S. Public Health Service show that uranium miners are exposed to radon gas, and limited investigation indicates that over a large part of the Intermountain area radon concentrations exceeding 10 micromicrocuries per liter of air can be found in virtually any mine.

Radon, being a gas, may diffuse from the wall rocks of a mine or be released during mining operations and become dispersed throughout the mine atmosphere. Radiation hazard in mining uranium ores results from the radioactive gas, radon, and two closely related products, RaA and RaC'. These elements are alpha emitters, and the energetic alpha particles damage body cells.

Radon gas is found in all the uranium mines of the Colorado Plateau area. The median number of micromicrocuries of radon in 132 samples from 48 uranium mines of the area was 3100 per liter.

The extent of the occurrence of radon in the nonuranium mines was somewhat unexpected. Radon was found in three Arizona copper mines in amounts of 8 to 300 micromicrocuries per liter. It also has been found in churn drill holes in a New Mexico copper deposit, in a lead-silver mine in Idaho, in a large Montana copper mine, and in metal mines, clay mines, and coal mines of Colorado. Five water-diversion tunnels were investigated, but no radon could be detected.

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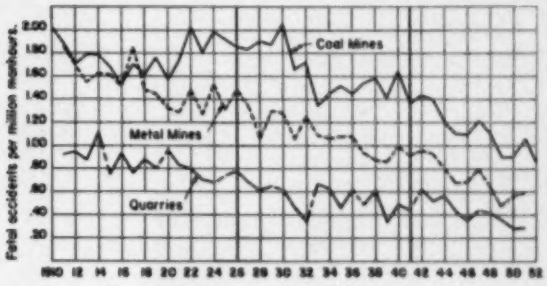

Fatal injury rates since 1911.

The daughter products of radon (RaA, RaB, RaC, and RaC') are not gaseous and have a half-life measured in minutes. A large part of these inhaled daughters will decay in the lungs; inhalation of the daughters is a much greater health hazard than inhalation of radon.

A relatively simple method of controlling this hazard in a mine is to sample the alpha emitters RaA and RaC', using a field method recommended by the Salt Lake City station of the U. S. Public Health Service. The hazards of radon can be largely controlled by the methods used to control dust in guarding against silicosis. Adequate ventilation is essential and natural ventilation cannot be relied upon.

A tentative standard of 100 micromicrocuries of RaA and RaC' per liter of air has been suggested by the Public Health Service.

Rock Bolting

Bolting as a systematic means of supporting the ground is now used by coal, metal, and nonmetallic mines and within the past 5 years has been used in tunneling. There are several reasons for this, but the principal one is that mechanization in mines has advanced to the stage where further progress will be retarded unless rock bolts are utilized to replace bulky conventional supports. As a byproduct of this move toward more efficient operation, it has been found that inherently this type of support lends itself to greater safety by preventing accidents from falls or slides of rock. Accident experience in metal and nonmetallic mines does not as yet indicate this influence clearly; however, experience in the bituminous mines that have adopted extensive roof bolting (in 1948-1949) reveals it quite vividly. As of Oct. 31, 1953, 639 coal mines and 140 metal and nonmetallic mines had adopted bolting as a systematic method of ground support.

From accumulated experience and the standpoint of utilization by the engineer, rock bolting may be classified in three categories:

1. *Suspension:* Pinning a loose piece of ground to ground considered to be self-supporting.

2. *Beam Building:* Considering a roof span as a simple beam, to provide early support by compacting, which will reduce total deflection to a point within the range of the elastic properties of the rock.

3. *Reinforcement of the Skin Area of an Opening:* To compact or reinforce an arch by providing additional resistance to compressive or shear stresses.

Trend in Roof-fall Fatalities

Period	Roof-fall fatalities	Roof-fall fatalities per million man-hours worked underground	Roof-fall fatalities per million tons mined underground
Average for 10 years, (1938-47)	467	0.74	1.04
1948	434	.77	.95
1949	259	.65	.78
1950	300	.68	.76
1951	298	.63	.72
1952	231	.57	.65
*1953 (Jan.-Nov.)	197	.58	.62

*Figures as of Dec. 4, 1953.

U. S. metal-mining districts are becoming more and more rock bolt conscious with respect to stopes; this is at best in the embryonic stage, and future progress in stope usage is virtually limitless.

Research

By September 1953 the number of approvals issued by the Bureau for permissible electrical equipment exceeded those issued in any previous year. Several foreign designs of equipment have been submitted for examination.

In search for quicker and cheaper coal extraction, operators are importing more and more electrical machinery for trial. Much of this meets the standards of the foreign country in which it was made, but standards and conditions may differ in many respects from those of the U. S. Usually standards in the U. S. are those prescribed by the Bureau. Because the Federal Coal Mine Safety Act restricts equipment used in gassy mines to that meeting the requirements of the Bureau, mine operators are faced with the problem of being cited for violating the law unless the Bureau can give relief; otherwise, they must abandon efforts to test foreign equipment.

Trolley-haulage systems have been responsible for many electrocutions and for many fires and explosions culminating in major disasters, particularly in coal mines. The mining industry is constantly seeking methods of underground transportation that do not require bare conductors as a source of power, such as trolley wire. New systems of mining and new types of equipment make it highly desirable that means be developed for producing better illumination at the coal face and in adjacent areas.

Disasters

During 1953 two major disasters befell the mining industry, one in a bituminous mine and one in (what will be classed as) a metal mine. Both disasters were preventable. Because of the wide publicity given to mine disasters and because such disasters will continue to occur if supervision is not drastically improved, a brief description of these disasters is included in this review:

About 8:10 a.m., Nov. 5, 1953, an explosion occurred in a portion of the open cut (trench) mine operation of the American Gilsonite Co., Bonanza, Utah. Eight men were killed and three slightly injured, two by burns and one by flying debris. The operation is in the Little Bonanza vein. This vein varies in width from 14 ft at one end to 11 at the other. As ore was removed, stulls were installed at least 25 ft apart, with intermediate stulls as needed. In some areas roof bolts were used. Three pillars of ore were left to provide protection from questionable wall structure above.

At the time of the explosion, a crew of five men were drilling and shooting the ore immediately under the most westerly pillar.

Evidence indicates that the flame originated on the surface at or near the head house, possibly at the elevator. The flame then entered the mine with sufficient intensity to propagate an explosion throughout the entire mine.

Of the possible sources of ignition, the most logical appears to be overheated power-driven equipment. The only equipment operating was the bucket elevator; therefore, it is assumed that this was the source of the initial ignition.

• • • •

A coal-dust explosion in the O'Brien mine, the O'Brien Coal Co., Lovilia, Iowa, about 4 pm, Mar. 30, 1953, killed two shot firers, the only men in the mine at the time. Their bodies were recovered at 6 pm that day. Three of five men who entered the mine about 9 pm, Mar. 30, reportedly to make an investigation of the explosion, collapsed and died of carbon monoxide poisoning. The other two men escaped to the surface; one was hospitalized until April 3.

The explosion resulted from two blown-out black blasting powder shots off the solid in No. 4 room, 10 west entry. The force of the explosion spread throughout 9 and 10 west entries, the only active section in the mine, and extended 700 ft in the main entries outby that section.

Fatal-Injury Rates

The fatal-injury rates continue to trend downward. From statistics available the fatal-injury rate for 1953 in all branches of the industry will be lower than in 1952. In coal mines the rate from Jan. 1 to Dec. 1, 1953, was 0.78 per million manhours. The general downward trend of accident rates, particularly during the last 27 years, is a good indication that further reduction of accidents can be expected.

The question has often been discussed as to why metal mining and quarrying are safer than coal mining, when a critical analysis of the mining environment shows that, in many instances, the hazards in metal mines are greater than in coal mines. Those who have worked in all branches of the industry are forced to agree that supervision is better in the metal and quarrying branches than in coal mines. Moreover, the contract system affecting the individual miner, as practiced in some coal mines, is not used in metal mines, and most accidents occur in the coal mines using the contract system, primarily because supervision is lacking and mining practices are not controlled as they should be.

It appears that as mining practices in coal and metal mines approach the mass production and controlled conditions of quarrying (open pits, continuous mining, controlled blasting, and transportation systems) the accident rates of coal and metal mines will compare more favorably with quarrying.

Mining industry has introduced safer mining methods, such as long-hole drilling from protected positions on sublevels, the use of scraper drifts instead of grizzly chambers, the adoption of well-installed and controlled blasting systems, and mechanical ventilation to insure removal of fumes from blasting or diesel equipment; more and more companies are using rock bolting to prevent accidents from falls or slides of rock.

Educational programs have been accepted by most safety agencies as the most effective method of reducing accidents. Records established by individual companies show that mining, as a whole, can be made comparable with other industries insofar as safety is concerned, provided effort is exerted and maintained and the individual worker and the supervisor realize that the worker is the focal point in the prevention of accidents.

Geophysical Discovery and Development Of The Pima Mine, Pima County, Arizona

A Successful Exploration Project

by Robert E. Thurmond,

Walter E. Heinrichs, Jr., and E. D. Spaulding

DISCOVERY of a commercial ore deposit has resulted from a program emphasizing geophysical techniques and concentrating upon exploration of alluvial-covered areas. United Geophysical Co. selected these areas as offering the best possibility of success, for here the surface evidence of ore deposits has been hidden from the eyes of prospector and geologist alike.

Pima mining district, Pima County, Arizona, was selected for initial exploration. The project was successful in that a commercial ore deposit was discovered and proved through drilling and extensive underground development.

A limited region of activity was chosen and library research was begun on available economic and regional geological publications relating to the mining districts. Field reconnaissance of those districts which seemed to hold exploration possibilities provided a general picture and ascertained the existence of alluvial-covered areas of interest. At the conclusion of the reconnaissance trips all data obtained were compiled, and the district which seemed to present the best exploration possibilities was selected by statistical methods. The statistical summary was based on the following considerations:

Geological Factors: 1—type of intrusive, 2—presence of favorable host rocks, 3—apparent intensity of mineralization, and 4—presence of favorable structure in covered or unexplored areas.

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Discussion on this paper, TP 3746A, may be sent (2 copies) to AIME before April 30, 1954. Manuscript, Dec. 10, 1953. New York Meeting, February 1954.

Economic Factors: 1—past production from district or mine; 2—size, shape, grade, and type of ore deposit in the district; 3—ease of acquiring mineral rights; and 4—general development facility.

Exploration Favorability Factors: 1—results to be anticipated from geological methods alone; 2—application of geophysical methods, namely, topographic conditions, surface interference, depth-size relation, physical property contrasts as related to ores or controlling structural features; and 3—drilling factors.

Admittedly, many of these factors do not lend themselves to absolute evaluation, but relative evaluation, subject to inaccuracies of personal judgment, is always possible. A relative scale from 1 to 10 was established for every factor, representing varying degrees of favorability. For each district a numerical evaluation of each factor was established and a numerical total determined. The obvious advantage of this scheme is that a more concise summation can be presented by numerical means than can be achieved by descriptive means.

After a district had been selected as favorable, the first step was to carry out more detailed geological and economic studies to narrow down the areas of interest. The second step was to compile all available geological data from publications and add to these data by mapping where necessary. Geological interpretation and projection of structural or other control into covered or unexplored areas was made whenever logical. To determine the possibilities of geophysical application and to select a geophysical method, physical property contrasts were related to mineral assemblages and/or structural control.

If geophysics seemed applicable, trial profiles were run crossing the area normal to the strike and spaced

The Transactions papers appearing in Mining Engineering during 1954 will subsequently appear in AIME Transactions Volume 199, and may be permanently referenced to that volume.

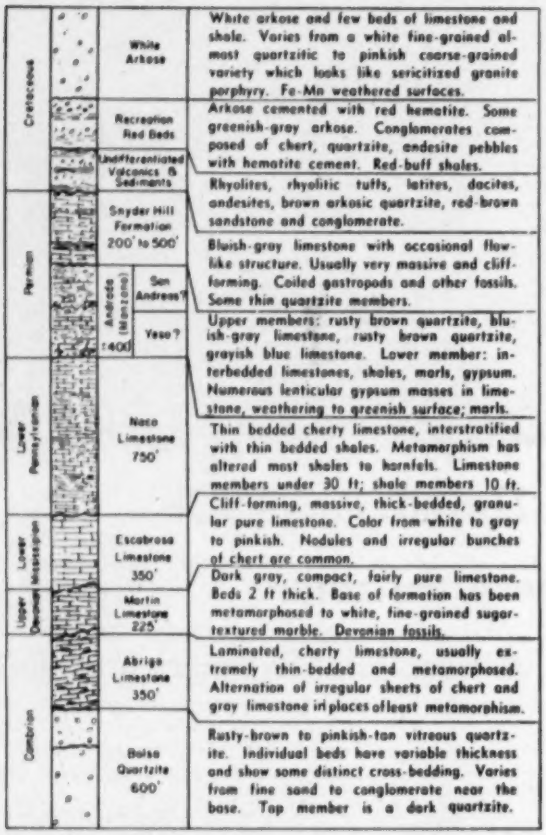
Cretaceous
White Arkose
White arkose and few beds of limestone and shale. Varies from a white fine-grained almost quartzitic to pinkish coarse-grained variety which looks like sericitized granite porphyry. Fe-Mn weathered surfaces.
Recreation Red Beds
Arkose cemented with red hematite. Some greenish-gray arkose. Conglomerates composed of chert, quartzite, andesite pebbles with hematite cement. Red-buff shales.
Undifferentiated Volcanics & Sediments
Rhyolites, rhyolitic tuffs, latites, dacites, andesites, brown arkosic quartzite, red-brown sandstone and conglomerate.
Permian
Snyder Hill Formation 200' to 500'
Bluish-gray limestone with occasional flow-like structure. Usually very massive and cliff-forming. Coiled gastropods and other fossils. Some thin quartzite members.
Andrade (Manzano) ±400'
San Andres?
Yeso?
Upper members: rusty brown quartzite, bluish-gray limestone, rusty brown quartzite, grayish blue limestone. Lower member: interbedded limestones, shales, marls, gypsum. Numerous lenticular gypsum masses in limestone, weathering to greenish surface; marls.
Lower Pennsylvanian
Naco Limestone 750'
Thin bedded cherty limestone, interstratified with thin bedded shales. Metamorphism has altered most shales to hornfels. Limestone members under 30 ft; shale members 10 ft.
Lower Mississippian
Escabrosa Limestone 350'
Cliff-forming, massive, thick-bedded, granular pure limestone. Color from white to gray to pinkish. Nodules and irregular bunches of chert are common.
Upper Devonian
Martin Limestone 225'
Dark gray, compact, fairly pure limestone. Beds 2 ft thick. Base of formation has been metamorphosed to white, fine-grained sugar-textured marble. Devonian fossils.
Cambrian
Abrigo Limestone 350'
Laminated, cherty limestone, usually extremely thin-bedded and metamorphosed. Alternation of irregular sheets of chert and gray limestone in places of least metamorphism.
Bolsa Quartzite 600'
Rusty-brown to pinkish-tan vitreous quartzite. Individual beds have variable thickness and show some distinct cross-bedding. Varies from fine sand to conglomerate near the base. Top member is a dark quartzite.

Fig. 1—Generalized columnar section, Mineral Hill area.

at wide intervals. Where possible, simple, rapid methods were first employed, after which the interesting areas were detailed. When a second geophysical method seemed applicable, the areas were re-surveyed. If the anomalous areas were apparent from results of two or more independent methods, interpretation and drilling considerations were facilitated. Since a reasonable geological hypothesis was already established, the geophysical interpretation consisted primarily of an estimation of horizontal and vertical location of the drilling target. This interpretation was checked against geological thinking to establish consistency in both sets of data.

Location and General Description

By the process of elimination just described the Pima mining district was chosen from some 30 districts. The Mineral Hill area where Pima mine is located was selected as one part of the Pima district to be investigated.

The Mineral Hill area is in the northeastern part of the Pima district, Pima County, Arizona, 20 miles southwest of Tucson. The district includes that part of the Santa Cruz river valley which is also the eastern slope of the Sierrita mountains. Most of the district is shown on the U. S. Geological Survey, Twin Buttes Quadrangle. Topography varies from flat to rugged, with numerous dry wash gulches. The usual brush, desert trees, and cactus cover the terrain, see frontispiece. Most of the area is accessible by good dirt roads and trails.

Past development in the Pima district followed the typical pattern of many western mining districts. Early production was in silver and copper. During this period two small smelters or furnaces were built at Sahuarita and Mineral Hill. Production continued until shortly after World War I, with a gradual decline to total inactivity by 1929. During World War II activity was resumed, significant lead-zinc-copper production coming from the San Xavier and other smaller properties.

At present, in addition to the Pima mine development, the Banner Mining Co. is developing its holdings and constructing a mill at Mineral Hill. Total production for the district is valued at over $20 million in copper, lead, zinc, silver, gold, and molybdenum.

Geology

The Sierrita Mountains are the most prominent physiographic feature of the Pima district. The northern portion of this range is the topographic expression of a batholithic mass of intrusive granite which comprises the main regional geologic structure of the district. Small sedimentary blocks of extremely complicated structure are exposed along the lower flanks of the range. Sedimentary structure is oriented east-west, roughly normal to the long dimension of the Sierrita range. Alluvial fans resulting from recent erosion of the range form a blanket of cover which overlaps the lower slopes of the mountains. In general, only the sedimentary blocks, particularly of limestone, have been resistant to erosion and so remain as hills surrounded by a blanket of alluvium. On the lower slopes where igneous rocks are exposed erosion has been greater.

The granite intrusion is thought to have occurred during the late Laramide time, although in some locations the coarse-grained texture of the igneous rocks and the lack of intense metamorphism along the sedimentary-igneous contacts has suggested the possibility of pre-Cambrian granite as well as younger intrusive granite.

In places both granites and sediments have been cut by later dikes which appear in a wide range of sizes, shapes, and composition. Volcanic rock which varies from rhyolite to basalt may be found in portions of the district. These are thought to be pre-Cretaceous, although some may be of a later period.

Sedimentary rocks exposed in the district range in age from Cambrian through Cretaceous. Generally speaking, these rocks may be correlated with established geological columns throughout the southwest. Fig. 1 is a graph representing the geological column.

Important ore deposits of the district can be fitted into the broad category of contact metamorphic deposits. In specific cases their characteristics vary, depending on their proximity to the related intrusive masses.

The Mineral Hill deposit is the only known deposit in the immediate vicinity of the Pima mine. The outcrop nearest Pima mine is exposed about a quarter mile west on Mineral Hill. Since the structural relations of Mineral Hill were a lead to the exploration of the alluvial-covered Pima area, a brief general description of the geology, structure, and ore relationships is pertinent, see Fig. 2.

Mineral Hill consists of two blocks of sediments separated by a major thrust fault striking nearly east-west and dipping approximately 50° to the south. These sediments form a small group of hills surrounded by alluvium except on the west side, where granite outcrops and is in contact with the

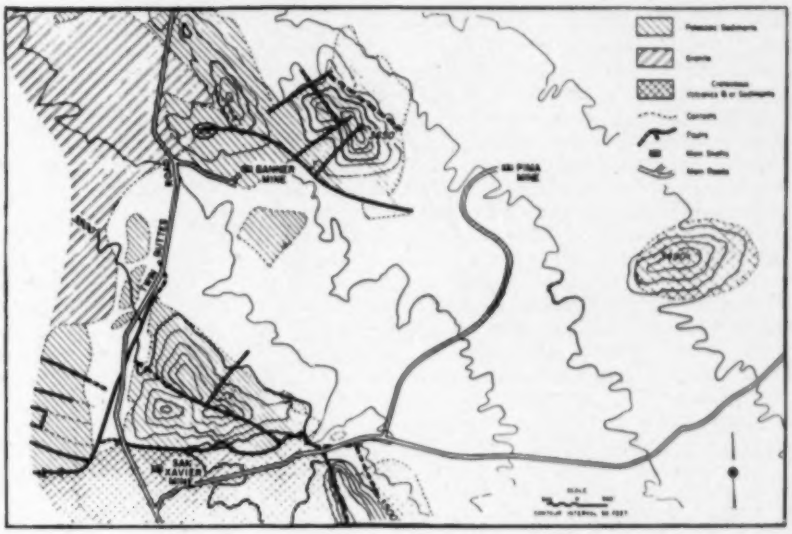

Fig. 2—Surface and general geology of the Mineral Hill area, Pima district, Arizona.

sediments. The western block of sediments is a reversed sequence with Cambrian, Devonian, Pennsylvanian, and Permian formations exposed from southwest to northeast and dipping steeply to the south. Much cross faulting results in complex structural relations within this block. South of the major fault Pennsylvanian and Permian sediments crop out in normal sequence, dipping steeply to the south; however, the structure here is somewhat obscured because of the alluvial cover on the lower slope of the hill.

The major thrust fault zone may have formed a channel along which igneous rocks have intruded the sediments. The ore deposits occur in favorable sedimentary members along the fault zone and in close proximity to the intrusive rocks. They are typical contact metamorphic deposits in that there is a normal contact-zoning of the high temperature gangue and ore minerals. The ore deposits are irregular in grade, shape, and distribution. The chief ore mineral is chalcopyrite, although locally bornite and chalcocite are present. In addition to the copper, minor amounts of zinc, molybdenum, and tungsten occur throughout the orebodies. Locally magnetite and pyrrhotite are present in varying quantities in close association with the ore minerals.

The apparent primary control of the deposits at Mineral Hill was the major thrust fault zone striking east-west. It was logical to assume that east of Mineral Hill there might be, under cover of alluvium, a continuation of this fault which would again cut favorable sediments. Possible blind ore deposits made this a good area for geophysical prospecting.

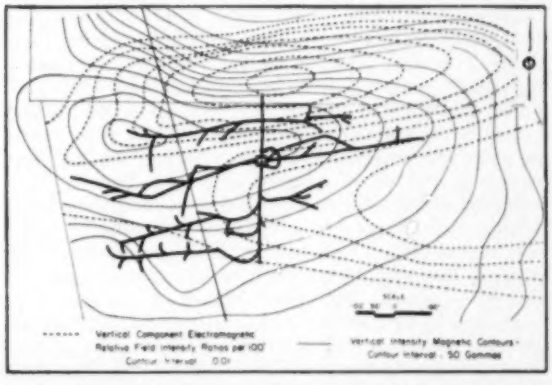

Fig. 3—Relationship between geophysical anomalies and the mine workings.

Geophysical Work

Investigation of known deposits in the district indicated that ore minerals, along with some associated gangue minerals, might possess sufficient physical property contrast with the country rock to support geophysical applications in the Pima district. To establish the magnitude of physical property contrast between the different rocks, in-place samples were taken from the surface and from accessible underground workings. The samples were tested for magnetic susceptibility, density, and conductivity. By means of these data and the size and shape of known orebodies, theoretical results to be expected from geophysical work were computed.

Results indicated that zones of magnetic concentration of the size expected could be detected with the magnetometer to a depth of 200 to 300 ft. Since much of the ore had been found in association with these zones, it was decided to make limited field tests with the magnetometer first, and if these were successful, more extensive surveys by other methods.

Preliminary magnetic tests were made by running long profile lines. A standard temperature-compensated, vertical intensity magnetometer was used. Readings were taken along the profile line every 12.5 ft, 25 ft or 50 ft, depending upon the rate of change between successive readings. Results of these tests were favorable in the Mineral Hill area and a detailed survey was started.

In this work stations were located with respect to a grid system. All readings were related to one main base station which was occupied each morning and evening. The overall accuracy of each observation, considering all errors, was no greater than plus or minus six gammas.

One important magnetic feature was delineated off the alluvial-covered eastern flank of Mineral Hill. This was called the Alpha area and was the site where prior geologic interpretation had indicated favorable possibilities, see Figs. 2 and 3. The magnetic high compared favorably with results obtained over other deposits that had demonstrated a close magnetic relationship to known mineralization.

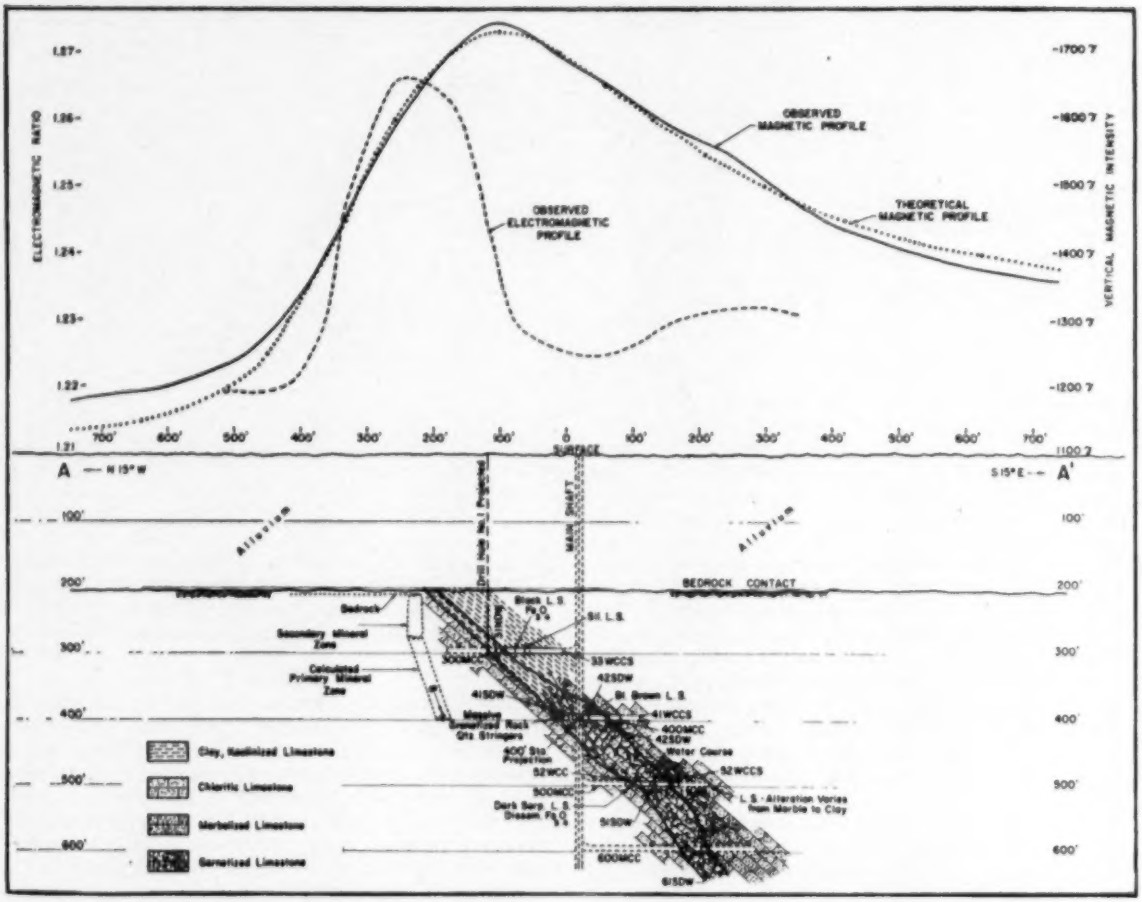

Fig. 4—Geophysical profiles and geologic section through A-A'. Geophysical bedrock and secondary mineral zone were estimated.

However, it was known that magnetite could occur without ore and that further information was desirable before a drilling program was planned. Investigation of the known mineral occurrences had also shown good electrical and density contrasts in addition to the magnetic properties. A study of the Alpha magnetic anomaly indicated a depth to the upper surface of the orebody of 210 ft, plus or minus 25 pct, see Fig. 4. This order of magnitude depth was confirmed in general by geological extrapolation and resistivity depth probing. Actual depths determined from drilling ranged from 205 to 215 ft. Calculations disclosed that work to this depth would be beyond the marginal limits of good gravity results, even with strong density contrasts. This suggested an application requiring an electrical method with penetration and resolution to at least 300 ft deep. Experience indicated that the electromagnetic method would be the most feasible. The required equipment was designed according to conventional principles and established procedures already used in the industry. Improved instrumentation provided maximum accuracy and dependability of results.

Field use of this equipment involved laying out a long wire grounded at each end, connected to a 400-cycle generator. Electrical measurements were made by comparing the electromagnetic field at two search coils across an electronic bridge with high amplification. Results of these measurements were plotted as relative field intensity ratios or phase angle differences in typical profile or contour form. An examination was then made of the areas of abnormal electrical gradient effects which would correlate with zones of unusual conductivity.

In the Alpha area an electromagnetic high was obtained which compared very well with the magnetic high, see Fig. 3. This evidence served to justify running a few experimental gravity profiles. Gravity results did not directly reflect a possible ore zone, but they did show an abnormality, probably due to basement structure, in the same location. Following the gravity work, a natural potential survey was made over the anomalous zone. This indicated a moderate oxidation area which coincided with previous information except that the center of highest intensity was offset to northwest. This was caused by more mineralization above the water table in that direction and by thinning of alluvial cover.

In compiling of geophysical data, corrections were kept to the minimum necessary to relate the observed values. Final interpretation was made by directly comparing the profiles or contour maps of results obtained from each method.

Summary of Surface Exploration: For the initial drilling, reliance was placed on the magnetic and electromagnetic results. Location of the first drill hole was based on an analysis of the magnetic data. The electromagnetic data confirmed this interpreta-

tion. Before drilling, geophysical analysis suggested that the orebody was a lenticular-shaped deposit dipping steeply to the south and striking nearly east-west. It was estimated that the upper surface of the ore was approximately 200 ft deep.

The first drill hole encountered bedrock and oxidized mineralization at 209 ft and sulphide ore at 255 ft. The samples of rock below the bedrock surface were highly magnetic and good conductors.

Development Program

Surface Drill Exploration: Upon completion of the first drill hole it was found that assays warranted a systematic drilling program to determine extent of mineralization and to provide sufficient knowledge for further interpretation of geophysical data. The first drill hole did not indicate a commercial deposit, but it did show the presence of copper mineralization. It should be noted that little or no prior information was available to guide the exploration, but the interpretation of the geophysical results was correct in direction of dip, depth of overburden, and general strike. Location of the second drill hole was guided from information obtained from the first, and all other holes were located by means of the magnetic contour map.

The pertinent problem required drilling through at least 200 ft of alluvium over the sub-outcrop. It was decided that standard diamond drilling practice in the alluvium would be impractical, but if oil field drilling methods were used, progress would be more rapid. The desired drill in the form of a Joy 22-HD was not available, but a Republic shot hole drill with a chain pulldown could be obtained.

Two strings of tools were used with the drill. To drill through the alluvium the tools used were 2⅜-in. diam drill pipe with a 3-in. diam drill collar and a Hughes W7R 3⅞-in. diam rock bit. Casing was set and cemented in the bedrock at any convenient hard strata. All coring was done with AX core barrels. To adapt the A rod for use on the Republic drill, a square kelly was fabricated with a chuck suited to the A rod. The kelly was fed through the rotary table by gravity, as no positive feed was available in the form of screw or hydraulic mechanism. This crude rigging was used until a Joy 22HD drill was purchased. The equipment mounted on a Ford, Marmon Harrington four-wheel drive truck consisted of the drill and a 4½x6-in. mud pump powered by the truck engine. The pump was rigged for use as a mud pump or as a clear water pump required when coring. This was accomplished by use of a bypass piped into the suction line. The multiple-purpose feature of the drill was successful in drilling either vertical or angle holes. It was not unusual to drill 200 ft to bedrock and set casing in one 8-hr shift. Eighteen holes were drilled, 16 completed, and 2 abandoned because of drilling difficulties before the mineralized zone was cut. Total footage drilled was about 7200 ft.

Underground Development: From the results of the drilling, a report was prepared recommending the sinking of an exploration shaft to 400 ft to explore the ore zone on the 300 and 400 levels. In November 1951 Pima Mining Co. was incorporated to carry out the program. Surface construction of the mine surface plant began in December. A shaft contractor was engaged to begin work on Jan. 1, 1952. Actual sinking was underway by Jan. 15. There was difficulty sinking through the 200 ft of alluvium, but nothing to retard progress seriously.

By May 1952 the 400 level station was cut. Lateral development on both the 300 and 400 levels started immediately following completion of the shaft stations. Two drifts driven east and west on the 400 level from the main crosscut explored the structure laterally for a distance of 925 ft. Concurrently the 300 level was explored laterally for a distance of 610 ft east and west of the main crosscut.

Following the exploration on two levels it was decided to sink to the 600 level. Nine holes were drilled from the 400 level, cutting the structure at varying depths. The deepest hole intersected the mineralized zone approximately 200 ft below the 400 level. Results from the nine holes encouraged further sinking of the shaft. Sinking commenced on Nov. 15, 1952, and by April 1953 the shaft was complete with stations at the 500 and 600 levels. This also included a permanent pump station on the 600 level capable of handling 1000 gpm.

Development of both lower levels was carried on concurrently, and by Sept. 1, 1953, the 500 level was explored laterally for a distance of 600 ft, the 600 level laterally for a distance of 400 ft. Lateral de-

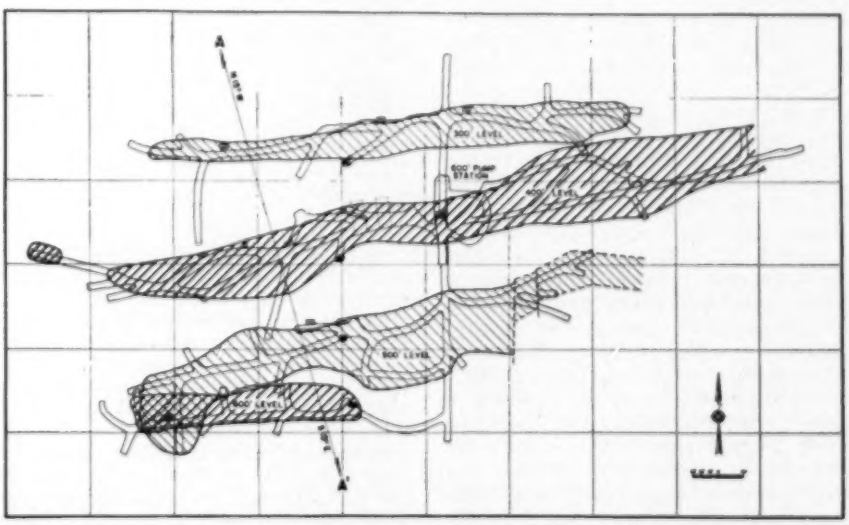

Fig. 5—Horizontal outline of ore shoots, all levels.

velopment on the lower levels is still in progress, although no work has been initiated east of the main crosscut on the 600 level. Preliminary diamond drilling has indicated a probably large volume of water in this section, and no work is proposed until the country drains.

Present activity is concentrated on vertical development and stope development. The width of the orebody and the ground characteristics require a stoping method dependent upon support and fill.

Experimental steps are in progress to prepare sections for a Mitchell slice system, and where ground conditions permit, a panel cut-and-fill system. Further work is required before a definite mining plan can be developed.

Underground Geology and Description of Orebody: The subsurface contact between the alluvial fill and country rock represents the suboutcrop of the orebody. It has been agreed that the section found in the mine consists of Paleozoic sediments and is separated from the Mineral Hill area by a possible north-south fault.

Degree of alteration varies widely throughout the mine. The mineralized zone is intensely altered, the alteration extending into both the hanging wall and footwall and decreasing in intensity perpendicular to the strike. The footwall proper consists of greenish-black chloritic material altered from limestone. The gangue material within the ore zone and locally on the hanging wall, particularly on the 300, 400, and 500 levels, is an intensely altered garnetized limestone. The garnetized limestone is an expression of alteration, but where the rock has been completely kaolinized alteration has been intense. The kaolinized material suggests the presence of porphyry, as there is some complete digestion with remnant limestone fragments included. Less intense alteration is expressed in the form of marbleized limestone. These instances are local and do not represent the general alteration pattern.

The degree of alteration normal to the walls varies widely in thickness from 20 to 100 ft or more. Ore mineralization is directly related to degree of alteration. Concentration of ore is associated with the garnet and kaolin zones.

The mineral assemblage represents that typically found in contact metamorphic deposits. Chalcopyrite is the principal ore mineral. Above the 300 level considerable secondary mineralization is present as chalcocite and native copper. The gangue minerals are epidote, garnet, magnetite, and calcium silicates, which are found throughout the orebody.

Mineralization and alteration are within a structural break that controls the deposition. Replacement is evident, but the fault zone appears to be the controlling factor. Cross-fracturing is present, but whether or not it is of importance is not known.

The orebody may be likened to a porphyry with phenocrysts of varying size representing the high-grade chalcopyrite, the matrix composed of intensely altered limestone containing chalcopyrite in disseminated form. The massive chalcopyrite is scattered and irregular in spacing and size. The localizing of the higher grade zones is not clearly understood, but a favorable limestone bed is probably a controlling factor. Alteration generally has destroyed any original identity, although a dark limestone present appears to be the favorable host rock.

Lateral and vertical development has not limited the extent of the deposit, although the lateral extent on the 400 level appears determined. The property line to the west limits exploration in that direction, and although mineralization weakens on the west side, the adjoining property has uncovered a possibly related orebody. Present exploration is concentrated to the east of the shaft, as little other work can be done to the west because of property limitations. Fig. 5 shows the width and lateral extent of the ore zone at the various levels.

Production and Future Plans: Shipments of ore from the mine commenced in May 1952 and have been continuous with the exception of a period between December 1952 and May 1953. Twenty-six thousand tons of ore containing 3,173,000 lb of copper have been shipped to the American Smelting and Refining Co. smelter at El Paso. Ninety percent of ore shipped was produced from mine development and 10 pct from stope development. Average grade of ore shipped, calculated from smelter settlement sheets, approximated 6 pct.

The orebody is of commercial milling grade, and sufficient tonnage of mill grade ore is in sight to warrant construction of a medium-sized concentrator. In conjunction with the mill, plans would require a new shaft, a surface plant, and preparation of the mine to deliver a minimum 350 tons a day.

The Pima mine is another example of successful application of mining geophysical methods. It is believed that its discovery is only a forerunner of the development of other hidden orebodies. Work at the Pima mine will not be completed until it becomes a profitable metal producer of the Southwest.

Acknowledgments

The authors are grateful for the support and guidance rendered by Herbert Hoover, Jr., Raymond A. Peterson, and M. G. Edwards throughout the project. They also appreciate the suggestions and advice given by B. S. Butler in the initial exploration phase and the interpretations made by Eldred Wilson of the geological problems.

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American Potash & Chemical Corp. Main Plant Cycle

by M .L. Leonardi

THE Searles Lake orebody is located in the northwest corner of San Bernardino County. It is a dry lake bed with an exposed salt surface covering an area of 12 square miles. Recoverable mineral values are contained in the mother liquor below the surface of the lake. Stratification in the lake bed has separated the brine into two bodies which differ in composition. Although liquor is processed from both bodies, this paper will discuss only the upper structure brine.

Fig. 1 illustrates a typical cross-section of the two commercial orebodies. The orebody is composed of a porous salt deposit 70 to 90 ft deep. The upper structure is separated from the lower orebody by a 12 to 16-ft thick impervious mud seam, as shown in Fig. 1. These salt structures are composed of 55 pct solid-phase salts and 45 pct voids which are filled with the original mother liquor.

The brine wells are drilled to the separating mud seam and cased to within 10 ft of the bottom. This is done to draw the brine horizontally from the bottom of the structure. It is pumped with multistage centrifugal pumps into the plant at the rate of 3 million gal per day.

The first process that was successful was developed by Charles P. Grimwood for the recovery of potash. The first evaporator unit was built in 1916. In the early twenties, Dr. Morse worked out a process for the recovery of borax. This made the cycle more efficient, as the end liquor could be sent back to the evaporators rather than being sewered. In 1926 the American Potash & Chemical Corp. was formed as a new company, and the entire plant was remodeled. The plant at that time produced only potash, borax, and boric acid. Since then the American Potash & Chemical Corp. has added processes for the production of USP boric acid, refined potash, sulphate of potash, soda ash, salt cake, lithium concentrates, Pyrobor ($Na_2B_4O_7$) bromine, phosphoric acid, and lithium carbonate.

The main plant cycle may be depicted as a closed cycle, see Fig. 2. The raw material, brine, enters the cycle to be mixed with the end liquor, known as ML2, from the pentahydrate borax crystallizers. The mixture of these two forms evaporator feed. Evaporator feed is pumped to the evaporators where it is concentrated, with respect to potash and borax. In the same operation water vapor, sodium chloride, salt trap salt, and clarifier salt are removed from the cycle, see Fig. 3 for potash plant product.

The evaporators produce a concentrated liquor which contains approximately 19.5 pct KCl. This liquor is diluted as it enters the potash plant to keep all salts, except potash (KCl, 97.0 pct) in solution. Here the moist potash leaves the cycle at 100°F. The end liquor, known as ML1, is pumped to the borax pentahydrate crystallizers, where crude borax pentahydrate is crystallized and removed as solid phase.

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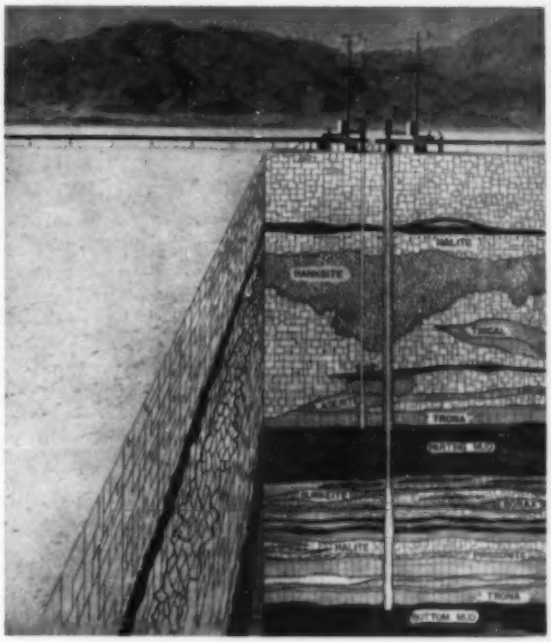


Fig. 1—Cutaway of Searles Lake salt structure.

The ML2 is sent back to pan feed to be reconcentrated, see page 207.

Note that the only water to leave the cycle is in the form of vapor and moisture in the solid phase products crystallized. Thus there is a constantly cycling volume of liquor to which brine is added. Since the volume of liquor cycled does not increase, the brine is, in effect, evaporated to dryness. This would be true if there were no liquor losses. But, as in all processes, there are always unavoidable and accidental losses which reduce the volume of cycling liquors. The losses must be made up with brine.

The concentration process is the beginning and the end of the cycling liquors. In this process there are three evaporator units of the triple effect countercurrent type, that is, there are three pans in each unit and the heat flows in one direction while the liquor flows the other way through the evaporator pans, see Fig. 4.

During the evaporation process a great deal of sodium chloride, burkeite, some sodium carbonate monohydrate, and a little lithium-sodium phosphate are crystallized. The volume of these salts is so great that they must be removed as they are formed or the process would come to a standstill.

Brine and recycled mother liquor No. 2 enter the third effect evaporator pan from the evaporator feed storage tanks, see Fig. 5. A steady flow of liquor is removed from the bottom of the No. 3 pan and is pumped through the No. 3 cone of the salt trap, a clear liquor being returned to the No. 3 pan. A portion of this clear liquor is pumped to the second effect pan. This process is repeated in each pan. The liquor from the No. 2 pan is pumped through the No. 2 salt trap cone and returned to the No. 2 pan.

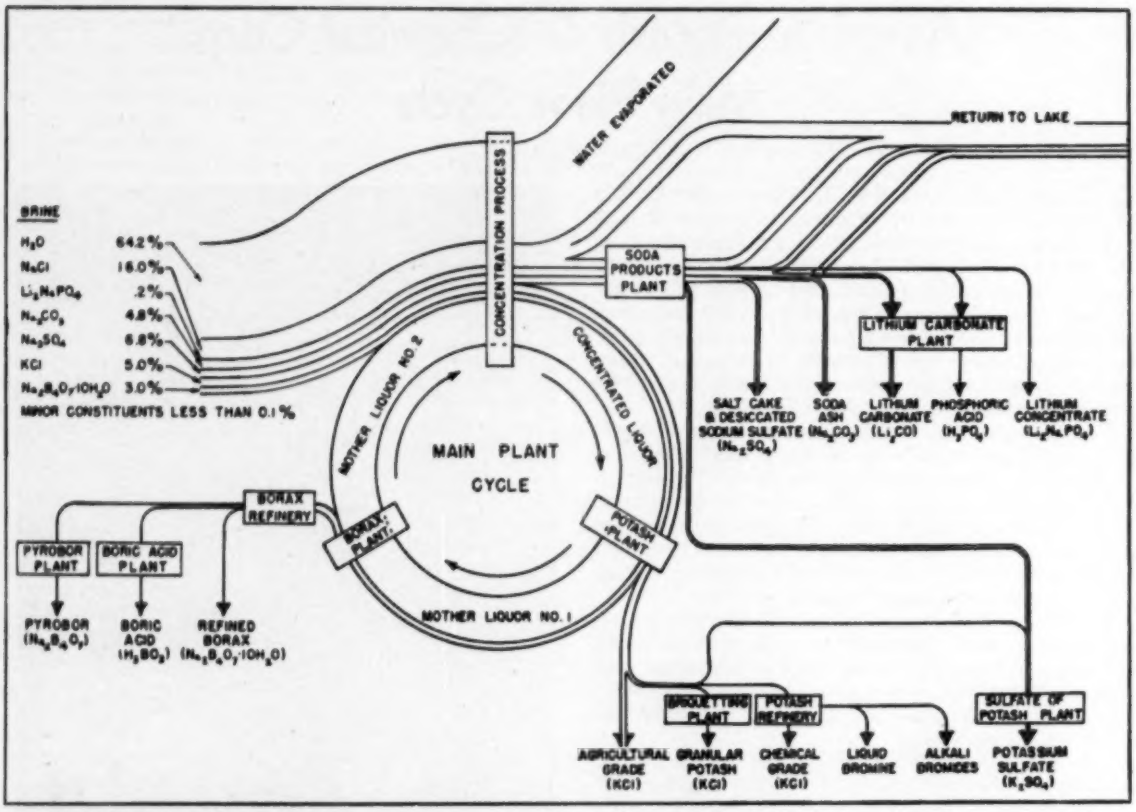


Fig. 2—Evaporator feed pumped to evaporators is concentrated, with respect to potash and borax, and in the same operation water vapor, sodium chloride, salt trap salt, and clarifier salt are removed from the cycle.

A portion of this liquor is advanced to the No. 1 pan. Finally, the liquor in the No. 1 pan is pumped to the No. 1 cone of the salt trap and clear liquor returned to the No. 1 pan. A portion is advanced to the clarifier cone, the amount being controlled by the KCl concentration in the liquor. It is desired to maintain a 36.5 g of KCl per 100 g of water.

The clarifier cone overflow is pumped to a 65-ft thickener. The clear overflow from the thickener is sent to two large storage tanks at the potash plant. The underflow from the salt trap is sent to a hydraulic classifier where the burkeite is separated from the sodium chloride. The underflows from the clarifier cone and concentrated liquor thickener contain burkeite, sodium carbonate monohydrate, lithium concentrates, and approximately 18 pct sodium chloride. These salts are sent to two 6x8-ft Oliver vacuum filters. To prevent flashing in the filters the temperature is reduced to 200°F by mixing with ML2. The salts are sent to the soda products system for processing and the filtrate is returned to the No. 1 pan for reconcentration.

The amount of concentrated liquor advanced to the clarifier cone determines the amount of pan feed pumped to the evaporators. It is necessary to maintain pre-determined levels in all the evaporator pans for proper operation. This is accomplished by transferring liquor ahead from the third-effect pan and controlling the level in the third-effect pan by feeding evaporator feed from the storage tanks.

The solid phase salts in the liquors from the evaporator pans are settled and separated from the liquors in the respective cones of the salt traps. Since the cones are superimposed in one vessel and are open at their apices, the combined salts leave through the bottom of the salt trap. This salt is either sent to 6x8-ft Oliver filters and then to a hydraulic classifier, or directly to the classifier. In either case the entrained brine is sent back to the No. 3 pan.

In the operation of the salt traps it is undesirable to return liquor from the first-effect pan which is highly concentrated to the third-effect pan where the liquor is weak. The salt trap is constructed to minimize this recirculating load. The liquor accompanying the salt as it enters the No. 2 cone from the No. 1 cone of the trap is displaced (or elutriated) from the salt by a flow of clear liquor from the No. 2 cone, which is returned, in part, to the No. 1 pan. This process of elutriation is repeated in each cone of the trap by pumping of the liquor from the cone below into the stream of advancing salt to produce a countercurrent flow, the salt down and the liquor up, in the same manner that the liquor is advanced in the evaporator pans.

The salt trap is rather small and will not separate the major part of the fine salts, namely, burkeite ($2Na_2So_4 \cdot Na_2Co_3$), sodium carbonate monohydrate, and lithium-sodium phosphate present in the evaporator liquors. As a consequence these materials travel on through and are settled in the clarifier cone and the concentrated liquor thickener. The underflows are pumped to 6x8-ft Oliver filters where the salts are removed from the liquor. The liquor is returned to the system and the salts are pumped to the soda products plant.

The losses in the evaporators are of three types: lost evaporation time, liquor losses, and dilution of

the liquor with water which must be evaporated. The evaporators must be regularly boiled out and the heaters washed out on schedule. These operations cause losses in all the above categories, though with careful supervision and improved techniques the losses are reduced to a minimum.

There are losses also at the filters, since it is impossible to remove all the entrained liquor from the salts being removed from the system. These filter cakes contain 12 to 16 pct moisture. The problem is one of balance; if the liquor is completely removed, too much wash medium enters the system. Brine is used to displace the liquor in the salt trap salt, since any brine entering the system becomes evaporator feed, and this filtrate is returned to the No. 3 pan.

In this triple effect evaporator system the liquor flows countercurrent to the heat. The path of the liquor and salt has been previously described. The reader may now follow the path of the heat through the system, see Fig. 6.

Heat enters the system in the first-effect heaters as 35-lb steam exhausted from the steam turbines in the powerhouse. The liquor is pumped from the bottom of the evaporator pan through four-pass external heaters and is returned to the pan near the surface, releasing water vapors. These vapors pass through separators, which remove any entrained liquor, and are sent to second-effect heaters where they heat the liquor in the second-effect pan. The liquor in this pan boils, releasing vapors which are used to heat liquor in the third-effect pan. Finally the vapor in the No. 3 pan is drawn to a barometric condenser and is condensed in the circulating spray pond water. The water in the brine thus leaves the system as condensate in the second and third-effect heaters and in the barometric tail water.

The humidity in Trona is normally low; therefore the barometric condenser water is pumped over induced draft towers. Since the vapor pressure of water in the atmosphere is below the vapor pressure of water at the temperature of the tail water, the latter will evaporate, giving up heat until the temperature has gone down and the vapor pressure approaches that of the atmosphere. The old natural draft towers have been replaced by induced draft types which are much more efficient.

In this concentration process 5 pct potash brine is combined with 11.5 pct potash ML2 to yield about a 7.5 pct potash evaporator feed, to produce about a 19.5 pct potash concentrated liquor, see Table I.

Here is a typical concentrated liquor analysis:

KCl	19.5
KBr	1.1
$Na_2B_4O_7$	10.0
Na_2CO_3	6.3
Na_2SO_4	1.6
Na_2S	0.7
P_2O_5	0.6
NaCl	7.0
H_2O	52.7

Though losses are undesirable in the system, they do prevent other salts from reaching concentrations that might interfere if they were not removed. One measure of the losses in the plant is the concentration ratio of some of these minor constituents in the brine. If the brine were evaporated to dryness they would precipitate; therefore it is obvious that they must have been lost while they were still in solution. Since liquor is lost from the cycle, the brine must be evaporated to the point where its volume equals the volume of the liquor lost. The I_2 concentration ratio is used to indicate the liquor losses. This ratio varies from 28 to 36, which means that the brine is concentrated until 1/28 to 1/36 of the original water is left before it is lost.

In these triple-effect evaporators, the evaporator feed enters the third effect at 125°F and boils at about that temperature. However, the liquor entering the second effect must be heated to 180°F, and that entering the first effect to about 250°F. The heat required to raise the temperature of the liquor, plus the heat lost by radiation from the surface of the equipment, reduces the amount of water evaporated by 1 lb steam to about 2.2 lb.

The heart of the evaporator system is a group of external heaters. Heat must be quickly and efficiently transferred from the condensing steam to the liquor or the process will slow down. The heaters are composed of a vapor space into which the steam

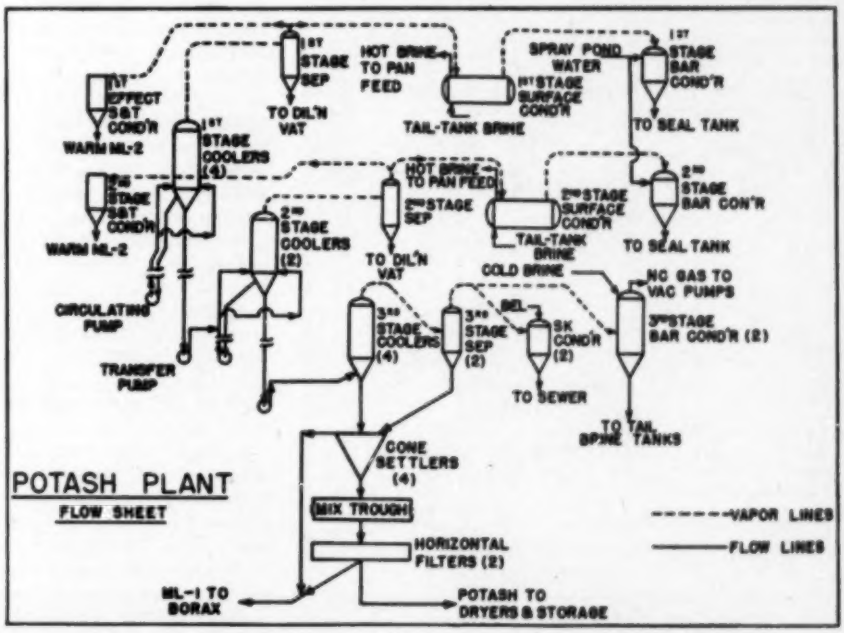
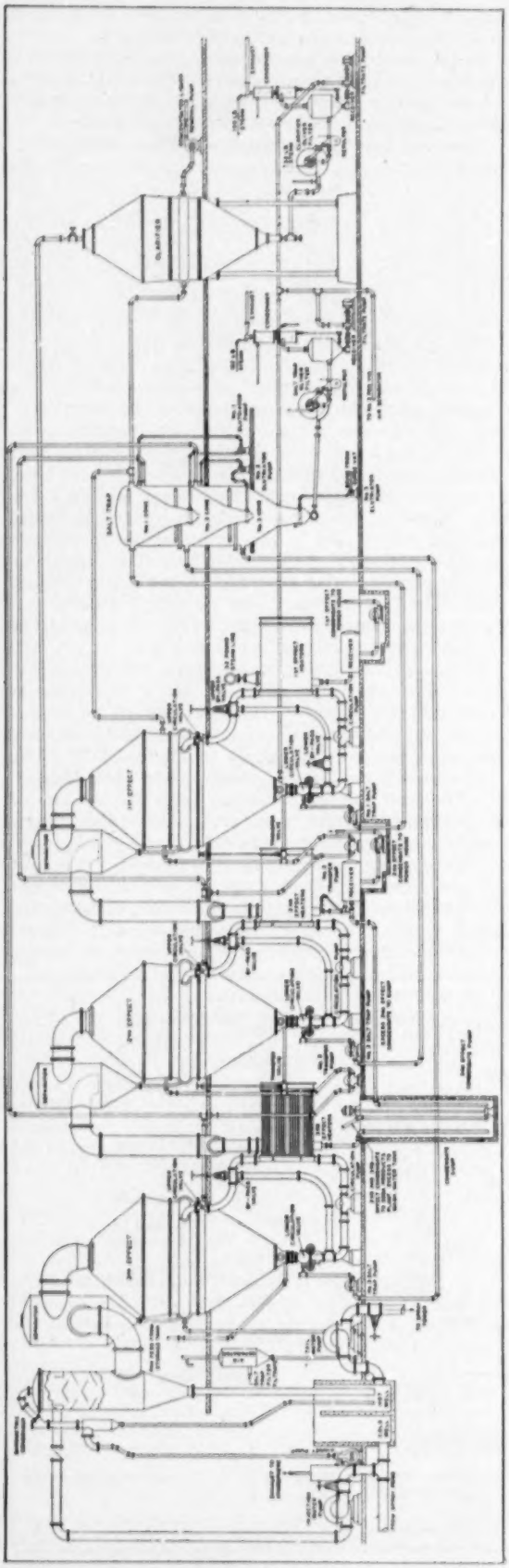


Fig. 3—In the crystallization process, the second step of the main plant cycle, the concentrated liquor is cooled to 100°F, the crystallized potash is settled in settling cones, and the settled material is filtered from the liquor in two 15-ft diam horizontal Oliver filters.



or vapor is introduced. Across the vapor space are stretched a number of tubes which carry the liquor back and forth four times in its passage through the heater. Condensate and noncondensable gas outlets are provided for the vapor space of the heaters. Heat passes from the steam condensing on the tube surfaces to the liquor within the tubes. The rate at which this transfer takes place depends on the following factors.

1—Steel tubes are used in the first-effect heaters and lead-coated Admiralty metal tubes in the second and third effect heaters. Steel tubes are satisfactory in the first effect because the virtual absence of oxygen from the powerhouse steam eliminates the corrosion problem. Aeration of steam from the first and second effect evaporators makes the use of lead-coated tubes necessary in the second and third effect heaters to prevent formation of a rust scale which would retard heat transfer. The lead coating also promotes dropwise rather than filmwise condensation which is desirable for better heat transfer. The scouring action of the salt prevents the formation of rust on the interior of the tubes.

2—The heater tube area was calculated to use up all the 35 psi steam produced by the powerhouse and refrigeration engines.

3—Heat transfer is effected by the difference in temperature between the liquor in the tube and the steam condensing on the outer surface of the tubes. Since the temperature of the liquor is rising as it travels through the heater, the heat transfer depends on the average temperature difference. The most accurate figure is the log mean temperature difference:

$$LMTD = \frac{T_{L_2} - T_{L_1}}{\text{Log.}\ \dfrac{T_s - T_{L_1}}{T_s - T_{L_2}}}$$

This method takes into account the change in temperature of the liquor as it travels through the heater tubes.

4—The low pressure steam to the first effect evaporator heaters is held at 35 psi. A change of 2 lb in steam pressure would give about 2°F temperature change, whereas a change of 0.1 in. mercury pressure in the third-effect evaporator pan would have a 2°F temperature change. For this reason it is important to maintain minimum pressure on the third effect pans. The vacuum on this system is maintained by circulating large volumes of water over the barometric condensers to condense third effect vapors. Two Kinney pumps per unit are used to remove the non-condensable gases formed during evaporation.

5—The liquor being a poor conductor of heat, it is desirable to have all particles of liquor come in contact with the tube surface to obtain maximum heat transfer to the liquor. This condition is maintained by circulating liquor through the tubes at a velocity of 4 to 5 fps.

6—The tubes are of 2-in. diam to give maximum surface and allow enough area to prevent plugging with salt.

Sodium chloride, burkeite, sodium carbonate monohydrate, and lithium-sodium phosphate are continually crystallizing from the liquors in the pans, and on the surface of the heater tubes. It is necessary that the heaters and the evaporator units be washed out on schedule to maintain the efficiency

Fig. 4—Diagram at left indicates operating data of evaporator units, salt traps, and interconnected auxiliaries.

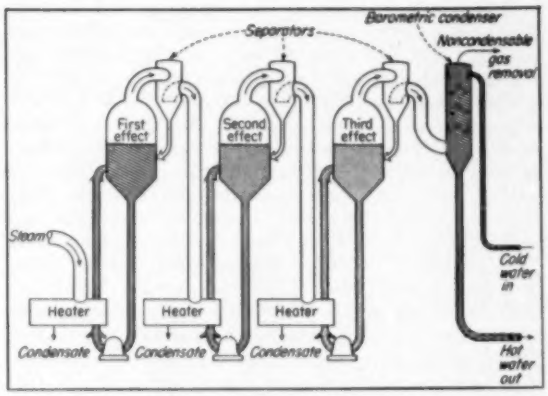


Fig. 5—Liquor advancement through triple-effect evaporators.

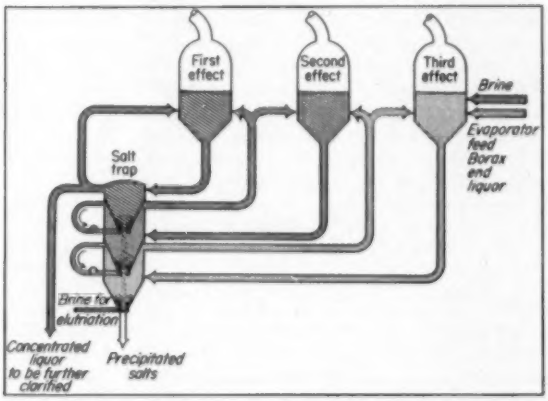


Fig. 6—The triple-effect evaporator unit heating arrangement.

of the evaporator units. The lithium sodium phosphate deposits in the first effect heater tubes, necessitating periodic acid washes to remove this scale.

In addition to salting, the evaporators have trouble with foaming and liquor entrainment in the vapors. Both cause losses from the concentration system. Droplets of liquor, thrown above the liquor surface by violent boiling, are carried upward and out of the evaporator by streams of vapor. These droplets are caught in the vapor separators and returned to their respective pans, see Fig. 6.

Foam caused much trouble at first, when these evaporators were developed. After much study, a cheap mixture of fatty acid, containing lauric acid, is continually added. This weakens the surface film and eliminates the foaming trouble.

In the evaporators some carbon dioxide is driven out of the brine by a reaction which may be expressed in the following manner:

$$Na_2B_4O_7 + Na_2CO_3 - 2Na_2B_2O_4 + CO_2$$

Owing to increased alkalinity, borate in the plant liquors becomes more soluble. This reaction is reversed by the addition of the carbonation plant borax which contains 20 to 30 pct $NaHCO_3$.

$$2Na_2B_2O_4 + 2NaHCO_3 - Na_2B_4O_7 + 2Na_2CO_3 + H_2O$$

The second step of the main plant cycle is the crystallization process. Here the concentrated liquor is cooled to 100°F and a crop of potash is recovered, see Fig. 6.

By checking it is obvious that concentrated liquor contains more KCl and $Na_2B_4O_7$ than pan feed, and contains less NaCl, Na_2SO_4, Na_2CO_3, and H_2O than pan feed. This is the result of evaporating H_2O and precipitating and removing the above salts from solution in the evaporating units.

The potash crystallization process is composed of cooling, settling, and filtering operations. This is accomplished by cooling the hot concentrated liquor to 100°F in vacuum coolers, settling the crystallized potash in settling cones, and filtering the settled material from the liquor in two 15-ft diam horizontal Oliver filters.

It is important to have a concentrated liquor almost saturated with respect to KCl. Since the liquor is saturated with NaCl, if KCl concentration is low there must be extra dilution to keep NaCl from crystallizing during KCl crystallization.

Table I. Analysis of Concentrated Liquor

Item	KCl, Pct	$Na_2B_4O_7$, Pct
Pan feed	7.5	3.8
Concentrated liquor	19.5	10.0
Mother liquor No. 1	11.5	9.8
Mother liquor No. 2	11.4	7.5
Brine	5.0	1.8

For example, if the liquor contains 37 g KCl per 100 g of water it would require only enough addition of H_2O to replace the amount lost from the liquor by evaporation in the potash vacuum coolers. On the other hand, a low-gram liquor (34 g per 100 H_2O) would require extra dilution to keep the sodium chloride in solution during crystallization in the vacuum coolers, thereby reducing the yield of potash and borax per cycle. The extra water must be evaporated in the concentration cycle.

In the diagram, Fig. 7, two polytherms are shown: one is the solubility curve for KCl in the temperature range of the KCl crystallization process; the other is the solubility curve for borax through the same range. Points A and A′ represent the percentage of KCl and $Na_2B_4O_7$ in the concentrated liquor. Points B and B′ represent the precentage of these two substances after dilution water has been added. Points D and D′, E and E′, and F and F′ represent the percentage of KCl and borax respectively in the liquors leaving the first, second, and third stages of cooling. Point C represents the approximate tem-

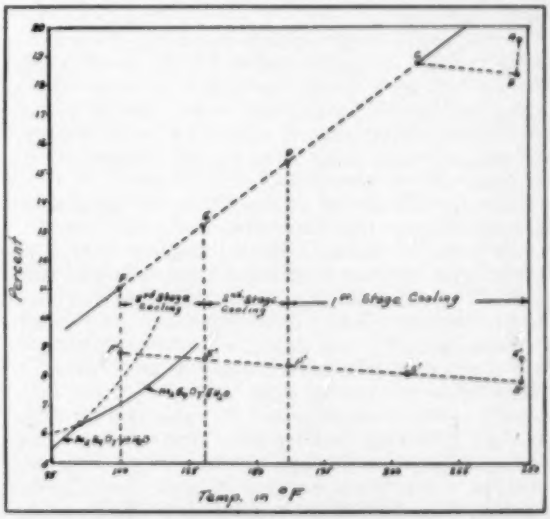


Fig. 7—Solubility curves for KCl and borax—see text.

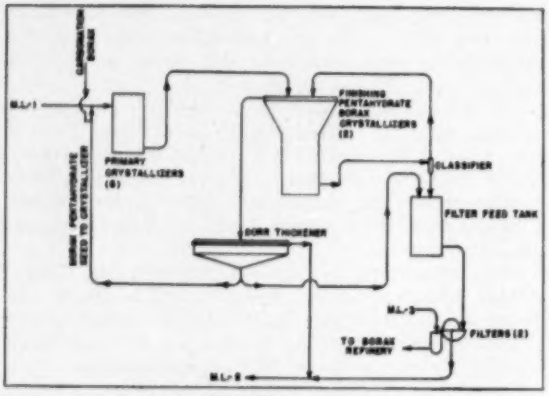


Fig. 8—Pentahydrate borax plant.

perature at which the diluted concentrated liquor becomes saturated with respect to KCl.

The line B′ E′ represents the path of borax concentration during the cooling process. Note that the concentration of borax remains almost the same between B′ C′ and increases slightly between point C′ F′. The reason for this increase in concentration is that water is evaporated and potash is removed, causing a reduction in the total weight of the liquor. Note also that the line C′ F′ passes through the borax solubility curve instead of following down the curve to lower concentrations as in the case of potash (KCl). It is evident that potash begins to crystallize from the liquor at about 205°F and continues to crystallize throughout the cooling range, while borax remains in solution. Furthermore, it is evident that the liquor becomes supersaturated with respect to borax while passing through the final stages of the KCl crystallization process. The reasons for the supersaturation are that in the tetraborate pentahydrate field there is an extremely slow rate of nucleus formation. The linear rate of pentahydrate crystal growth is also slow in these liquors.

The tendency for a hydrated salt-like borax to crystallize as a metastable solid phase at a temperature above its stable range is much more than at temperatures below its transition point. Thus because of high rate of liquor flows through the third-stage potash coolers, short retention time, and lack of violent agitation, the supersaturation conditions are easily maintained.

In vacuum cooling heat is removed by the vapors in the vacuum crystallizer; thus the liquor is cooled. The reasons for cooling this liquor in three stages instead of one are as follows: more efficient use of the coolant, better control of the borax impurities, and smaller vapor lines from coolers to condensers, see Table II.

Note that volume of vapors from the third stage is approximately five times that of the first stage.

Raw brine is used as a cooling medium instead of H_2O for two reasons: 1—Brine coming from the lake at 76°F is cooler than any available cooling H_2O during the summer months. 2—Brine has a lower vapor pressure than H_2O and thus is equivalent to H_2O of 64°F when used in a barometric-type condenser.

The brine is used through two barometric condensers on the third stage and then pumped in series through two tube condensers: first through the second stage, then through the first stage, thus recovering a maximum amount of heat from liquors being cooled. The brine is heated to 125°F while cooling the liquor to 100°F. In recent years, owing to increased capacity of the concentration process, it has been necessary to supplement the third-stage cooling with 400 gpm of soda products plant end liquor (BEL) which is sent to the coolers at 72°F.

The potash end liquor (known as ML1) at 100°F is pumped to the borax plant. This liquor is saturated with potash and supersaturated with respect to sodium tetraborate pentahydrate. This liquor is seeded with fine sodium tetraborate pentahydrate from the borax plant Dorr thickener underflow and carbonation plant borax and sodium bicarbonate. This liquor is fed into two parallel sets of three primary crystallizers connected in series. The overflow from the primary crystallizer is pumped into two large agitated crystallizers operated in parallel. These tanks have approximately 45 min retention time and maintain sludge density of 40 to 44 pct sodium tetraborate pentahydrate as a seed mixture.

In this manner the stable sodium tetraborate pentahydrate is brought to equilibrium in solution. The coarse crystals are removed from solution by circulating the sludge from the bottom of the crystallizer through two cyclone classifiers. The coarse crystals are discharged from the bottom of the classifiers into a filter feed tank, whereas the fines are returned, as seed, to the system with the solution out of the top of the cone separators, see Fig. 8.

Table II. Volume of Vapors

Stage	Vapor Temp.	Liquor Temp.	Specific Volume of H_2O Vapor, Cu Ft Per Lb
3rd stage	80°F	100°F	632.9
2nd stage	110°F	130°F	265.4
1st stage	140°F	160°F	123.0

The overflow from the main crystallizers contains 8 to 15 pct fine suspended solids. This liquor flows to a 60-ft Dorr thickener. The overflow from the thickener, ML2, and the filtrate from the crude Oliver filters is combined and pumped through the Potash plant where it is used as a coolant in the first stage vertical tube condensers, then pumped to pan feed tanks where it is mixed with hot brine to form feed for the evaporator units. The underflow from the thickener is pumped back to the primary crystallizers as seed, see Fig. 8.

The crude tetraborate pentahydrate can be processed crude by pumping it directly to the Sharples centrifugals and drying it (this is sold as Tronabor), or it can be pumped on to two 13-ft diam horizontal Oliver filters, dewatered, washed, redissolved, filtered to remove physical impurities, and either recrystallized as refined tetraborate pentahydrate or decahydrate, depending on market requirements for these products.

Acknowledgments

This paper was condensed from company research department files and from W. A. Gale's report on the geology of Searles Lake presented at the AIME meeting in Los Angeles, February 1953. This process and equipment has been modified, developed, and adapted to process Searles Lake brine by the many engineers who have worked in the research and production organization since 1916, when C. P. Grimwood built the first evaporator unit. P. S. Dunn, Vice President in charge of technical operations, and R. W. Mumford, Vice President and Consultant Engineer for American Potash & Chemical Corp., made it possible for the writer to present this paper and helped plan and organize the potash symposium presented at the AIME meeting in 1953.

Flotation Characteristics of Pyrrhotite with Xanthates

by C. S. Chang, Strathmore R. B. Cooke, and Iwao Iwasaki

The effects of aeration on an aqueous suspension of pyrrhotite were studied and their results correlated with flotation tests using xanthates as collectors. The effects of copper activation and of pH variation were determined and possible mechanisms postulated.

PYRRHOTITE has long been considered a gangue mineral to be eliminated as tailing in the treatment of various sulphide ores. However, in recent years the world-wide lack of sulphur resources has called attention to this mineral as a potential source of both sulphur and iron. Its importance as an economic mineral, however, has not been particularly emphasized. For this reason very little is known about its response to flotation, except that it can be depressed easily in alkaline circuit, by long aeration,[1, 2] addition of oxidizing agents,[3] or by starch.[4]

The object of this work was to study the floatability of pyrrhotite. This includes the effect of oxidation by aeration, of copper activation, and of change in pH.

Preparation of the Pyrrhotite Sample: It was desirable that the highest grade of pyrrhotite obtainable be used for this experiment, since the presence of other minerals could affect the surface properties.[5] However, no pyrrhotite was available as crystals, and massive deposits of hydrothermal origin commonly contain considerable amounts of chalcopyrite. Pyrrhotite concentrate was, therefore, prepared from a sulphide deposit occurring near Aitkin, Minn. The deposit is of pyrometamorphic nature consisting mainly of pyrrhotite and pyrite with graphite, silicates, and carbonates as gangue.

The ore, already crushed through 3 mesh when received, was screened at 65 mesh and the undersize discarded. The oversize was crushed through rolls, and then stage-ground dry in an Abbe porcelain mill, the −65 mesh portion being screened out after every 15 min of grinding until all the material passed through this size. The ground product was then concentrated with a drum-type dry magnetic separator. The rougher concentrate was cleaned twice and then demagnetized. The final product was split in a Jones splitter and stored in air-tight bottles. Microscopic examination of the concentrate showed that it was relatively clean and free of pyrite, locked particles, and gangue. By means of the krypton gas adsorption method,[6] the specific surface was determined to be 3000 cm^2 per g. The chemical and screen analyses of the final concentrate are given in Tables I and II respectively.

It is a well-recognized fact that the oxidation of some sulphide ores during stockpiling, grinding, and conditioning affects their flotation behavior. The problem of oxidation may become serious in the case of pyrrhotite, since this is known to be more easily oxidized than many other sulphides. To ascertain the extent of oxidation, an experiment was carried out by aerating an aqueous suspension of pyrrhotite with air, oxygen, and nitrogen as follows.

A 300-g sample of pyrrhotite in 2700 ml of water was agitated and simultaneously aerated in a Fagergren-type laboratory flotation machine. A Precision wet test meter was connected to the air inlet valve, the flow rate of the gas being kept constant at 0.3 cu ft per min throughout the experiment. Samples of approximately 30 ml each were taken from the cell at 0, 4, 10, 20, 35, 60, and 90 min. After the pH was taken, each sample was filtered and the filtrate was analyzed for total iron and sulphur.

The iron was determined colorimetrically by the thioglycolate method using a green filter.[7] The filtrate was oxidized with bromine to convert all of the soluble sulphur compounds into sulphate and this was determined with a Parr turbidimeter.[8]

When aeration tests were made in alkaline circuit, calcium hydroxide or sodium hydroxide was added at regular intervals to maintain a constant pH.

A similar procedure was followed in an experiment to determine the abstraction of copper ion by pyrrhotite. In this case various quantities of cupric chloride were added. The filtrate from each sample taken was analyzed for copper, total iron, and sulphur. The carbamate method with a green filter was used for the copper analysis,[7] since this method could tolerate a considerable amount of iron in the solution.

A pneumatic cell, made from a 350-ml fritted glass Buechner funnel, was used for this experiment. The detail of the assemblage has been described elsewhere.[9] In the present work a stainless steel baffle was inserted in the cell. This baffle overcame the tendency for the coarse pyrrhotite particles to be swirled around the wall of the cell and thus fail to collect in the froth.

A 50-g sample of pyrrhotite was added to the cell which contained 260 ml of water. When pretreatment of the sample was desired, reagents, such as activator and pH regulator, were then added and the pulp was conditioned for a specified conditioning time. Prior to the addition of the collector approximately 15 ml of the solution were removed for pH measurement and for iron and sulphur analyses. Copper when used as activator was also determined. Collector and frother were then added and the pulp was conditioned for an additional 2 min. Air was admitted to the cell and the froth removed. The separation required from 4 to 6 min, depending on the characteristics of the froth.

The float and non-float products were filtered, dried, weighed, and assayed for iron.

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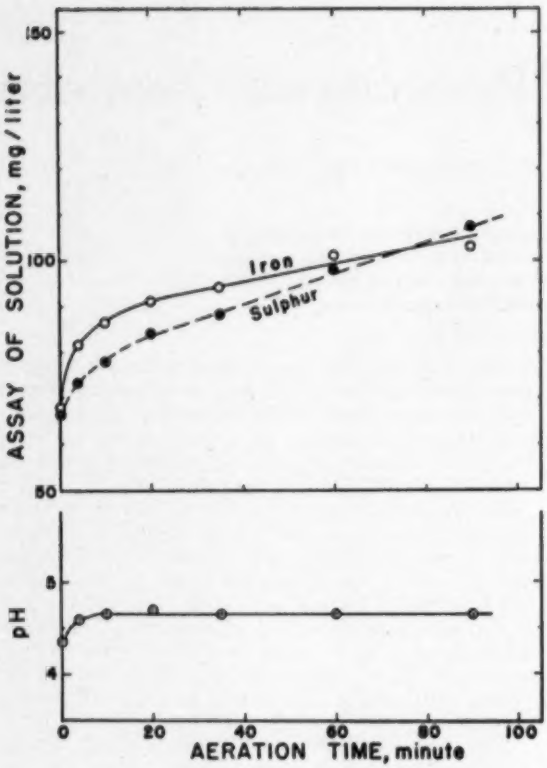


Fig. 1—Aeration test with air.

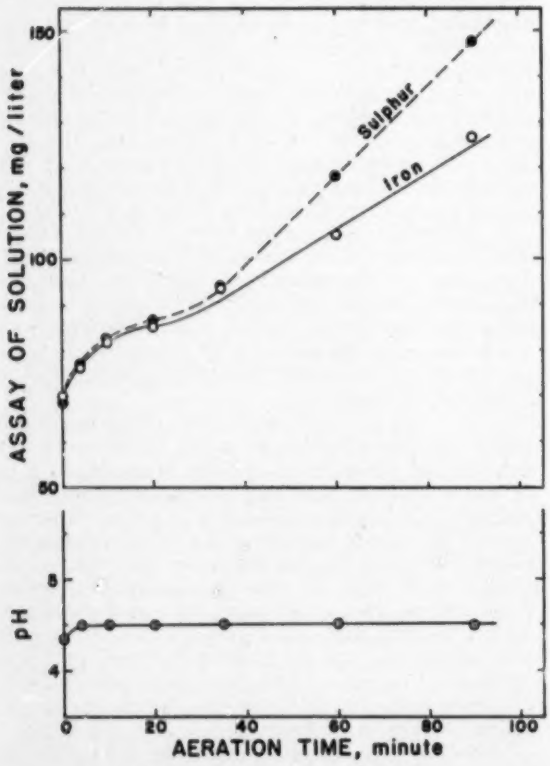


Fig. 2—Aeration test with oxygen.

After each flotation test, the cell was thoroughly washed with hot water and rinsed with demineralized water. Occasionally the cell was boiled with aqua-regia to remove fine mineral particles plugging the pores of the fritted glass.

Table I. Chemical Analysis of Pyrrhotite Concentrate

Item	Pct
Fe	48.21
S	31.16
SiO_2	12.74
Al_2O_3	2.73
Total C	1.21
Graphite C	0.88

Table II. Screen Analysis of Pyrrhotite Concentrate

Size, Mesh	Wt, Pct	Fe, Pct
−65 +100	17.64	55.76
−100 + 150	14.96	55.92
−150 + 200	11.95	56.08
−200 + 270	6.20	54.47
−270 + 400	12.28	47.65
−400	36.97	38.09
	100.00	48.21

The following reagents were used for the preceding tests:

Collector: The potassium ethyl and n-amyl xanthates used in this experiment were synthesized in the usual way.[10] All the chemicals used for these preparations were of analytical reagent grade. The products obtained were placed in evacuated pyrex bottles and stored in a refrigerator. In general, a 1.0 pct solution was used for addition.

Frother: Several frothers were tested and B-23 gave the best frothing characteristics. It produced a fairly dry froth consisting of medium-sized bubbles, and a comparatively small quantity of material was mechanically carried over. The frother was diluted 20 times by volume with ethyl alcohol and 1 to 2 drops of the solution were usually added. One drop of this solution was equivalent to 0.02 lb per ton of ore.

Other Reagents: The pH regulators, such as sodium hydroxide, hydrochloric acid, calcium oxide, and sulphuric acid, and the activator, cupric chloride ($CuCl_2 \cdot 2H_2O$), were of analytical reagent grade. The nitrogen and oxygen used had a listed purity of 99.5 pct. Demineralized water containing less than 0.1 ppm of salts as NaCl was used in the preparation of all solutions and for all test work.

Experimental Results

Aeration and Copper-Abstraction: A preliminary test was made for the presence of ferrous, ferric, and sulphate ions in the filtrate from an aerated aqueous suspension of pyrrhotite. All the iron present was in the ferrous state and remained so for a period which was of the order of several days to a few weeks. Sulphate ion was also present, but the quantity increased when the filtrate was oxidized with bromine. This indicated the presence of soluble sulphur compounds other than sulphate.

1—Aeration at Natural pH: Three aeration tests were made with air, oxygen, and nitrogen respectively. These three tests were performed within one week to minimize any serious sample alteration during storage. The results are plotted against time in Figs. 1, 2, and 3. They show that liberation of soluble ions is rapid in early stages but approaches a constant rate as aeration time is increased.

With nitrogen, Fig. 3, initial liberations of iron and sulphur are the highest of all. After about 20 min of aeration, however, both iron and sulphur pass into solution at the same rate. With oxygen, Fig. 2, and after the initial stage, the rate of liberation of soluble ions is greater than with air, Fig. 1. In both cases the rates for sulphur are greater than those for iron, suggesting precipitation of the iron during the process. The samples from these tests, when dried, gave a much more reddish color than those obtained with nitrogen.

Constant pH values of 4.5, 4.65, and 5.1 were reached with oxygen, air, and nitrogen respectively and will henceforth be referred to as the corresponding *equilibrium pH*. This would seem to indicate that the pyrrhotite provides buffering action to the pulp.

2—Aeration at Alkaline pH: A similar experiment was carried out with air in an alkaline circuit. The pH was maintained at approximately 8.5 by the addition of calcium hydroxide or sodium hydroxide at regular intervals. Results are shown in Fig. 4.

No iron was present in the solution. The sulphur was liberated in the same manner as in the previous experiment but in larger quantity and at a higher rate. At equivalent pH, the rate was greater for sodium hydroxide than for calcium hydroxide.

3—Aeration in Presence of Cupric Ion: Aeration tests with addition of 0.7, 3.4, and 6.9 lb of cupric chloride ($CuCl_2 \cdot 2H_2O$) per ton were made. These represented initial concentrations of 14.4, 71.7, and 143.5 mg respectively of copper per liter of solution. Only air was used in this experiment. The results are given in Figs. 5, 6, and 7. They show in all cases a depletion of copper from solution, in agreement with the early finding of McLachlan.[11] The time for complete copper removal depends on the initial copper concentration. The amount of sulphur passing into solution is almost constant regardless of the amount of copper added, and it is relatively less than that when copper is absent. However, the quantity of iron liberated depends on the quantity of copper abstracted.

It should be noted that the initial sample was taken after 15 sec of agitation without aeration and a considerable amount of copper was removed from solution during that time. This accounts for the lower copper concentrations reported at zero time compared with that initially added.

To investigate the possibility of any color change due to activation, polished specimens of massive pyrrhotite from Kimberley, B.C., mounted in lucite, were agitated in 0.35 and 1 pct cupric chloride solutions for 15 hr at room temperature, 25°C. One half of each specimen was coated with paraffin while the other half was exposed to the copper solution. For photomicrographs of tested specimens, see Fig. 8.

Depending on the time of exposure to the cupric chloride solution the exposed surfaces ranged from a brass-yellow to a highly-irridescent peacock color. Local precipitation of an unknown substance roughened the surface. The specimens contained inclusions of chalcopyrite, sphalerite, and pyrite, and these showed no change in color. Some difference in shade of color was noted among the pyrrhotite grains, Fig. 8b, indicating that copper attacked preferentially along certain crystallographic directions.

A similar experiment was made in a 10 pct cupric chloride solution at a temperature of 50°C. The pyrrhotite surface was completely obscured by a

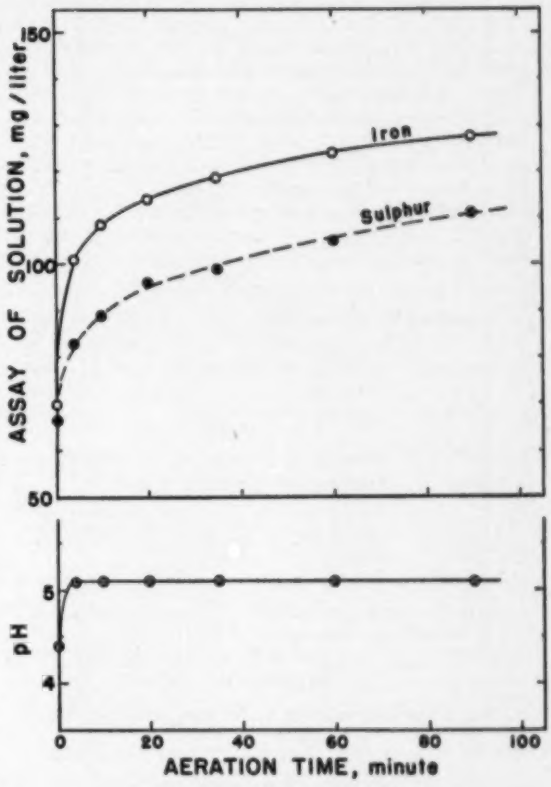


Fig. 3—Aeration test with nitrogen.

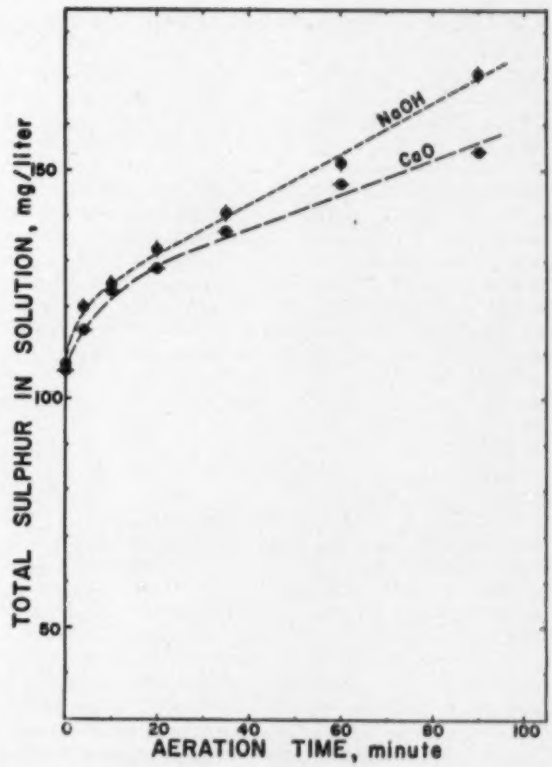


Fig. 4—Aeration test at pH = 8.5.

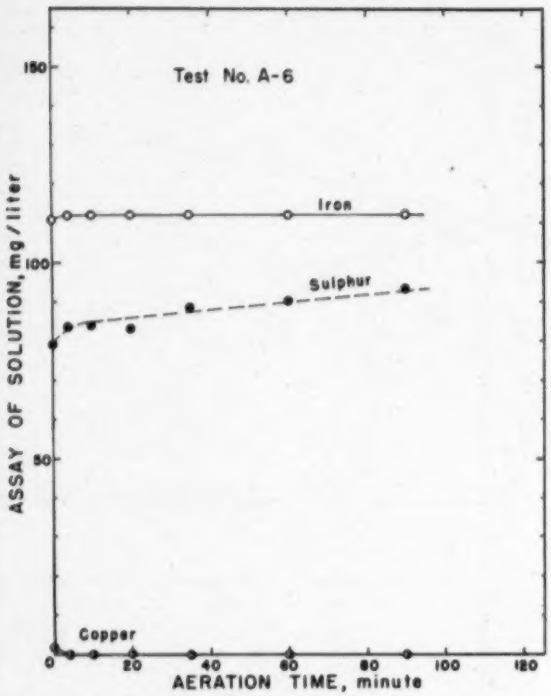


Fig. 5—Aeration test with 0.7 lb $CuCl_2 \cdot 2H_2O$ per ton.

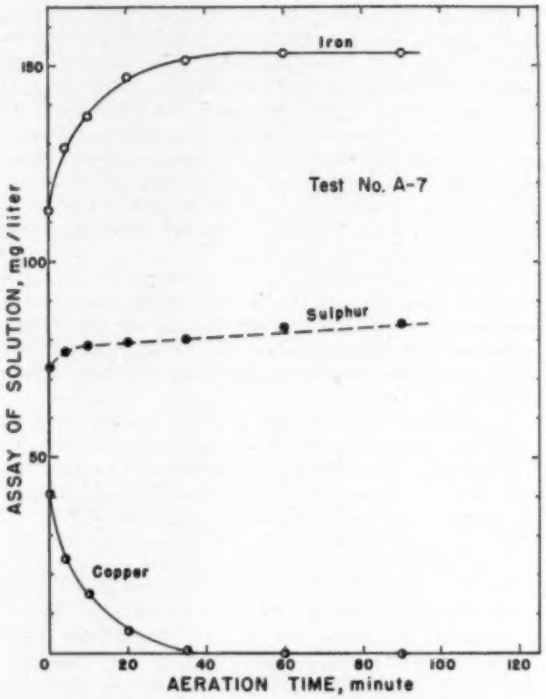


Fig. 6—Aeration test with 3.4 lb $CuCl_2 \cdot 2H_2O$ per ton.

precipitate containing iron but otherwise of unknown composition.

Flotation: All flotation tests, unless otherwise specified, were made at the natural pH of the pulp, i.e., 4.5.

1—Effect of Collector Addition With and Without Copper Activation: Two series of flotation tests were performed. Potassium ethyl xanthate was used as collector in one series and potassium amyl xanthate in the other. The collector addition ranged from 0.4 to 6.4 lb per ton of pyrrhotite. In two similar series of tests pyrrhotite was first conditioned with 1 lb cupric chloride per ton for 15 min prior to flotation.

All the data from these flotation tests are plotted in Fig. 9. Without copper activation the recovery was rather poor and even at a collector addition of 6.4 lb per ton, the recovery was only 28.9 pct with ethyl xanthate and 53.3 pct with amyl xanthate. On the other hand, with prior activation, the recovery was increased approximately 20 pct at the same collector addition. However, the general shape of the curves indicates that it would require extremely large quantities of collector for complete recovery. It was noted from visual observation that non-float products consisted mainly of the coarser portion of the original sample.

2—Effect of Collector Addition in Stages: In this experiment, the collector was added in stages and float products were collected separately after each addition. The cumulative amount of collector at each stage was arranged to correspond with those of single addition in the previous experiment. The results are shown in Fig. 10 with the cumulative percent iron recovered plotted against cumulative amount of collector added. Comparing Figs. 9 and 10, it can be seen that the same total amount of collector, added stagewise, gives much improved recovery. For example, 3.2 lb amyl xanthate per ton added in stages gave about 96 pct recovery of activated pyrrhotite, whereas a single addition of the same quantity of collector gave a recovery of only about 50 pct.

To study the size distribution, screen analyses were made on all flotation products obtained in these tests. The cumulative percent weight recovered in each size fraction is plotted in Figs. 11 and 12 against the cumulative amount of collector added.

The results show that the floatability of pyrrhotite decreases with increase in particle size. This tendency is most pronounced when ethyl xanthate is used as collector to float unactivated pyrrhotite with the +200 mesh particles responding very reluctantly to flotation. The results also confirm the increase in floatability with copper activation.

3—Detrimental Effect of Excess Cu^{++} ion in Pulp: Even though copper activation of pyrrhotite increases its floatability, the presence of excess Cu^{++} ion in the pulp precipitates xanthate according to the following reaction, and the presence of excess Cu^{++} ion is undesirable.

$$4\,ROCSS^- + 2\,Cu^{++} \rightarrow 2\,ROCSS \cdot Cu + (ROCSS\text{-}SSCOR)$$

This is demonstrated by two flotation tests in which the pyrrhotite was conditioned with 5 lb of cupric chloride per ton for 15 min and 2 hr respectively and the amyl xanthate was added in increments. The results are given in Fig. 13 together with those of Test No. 22 already shown on Fig. 10. Copper analyses were made on the pulp solution prior to collector addition and the results are given in Table III.

Fig. 13 shows that for the same recovery more collector is required as excess Cu^{++} ion is increased in the pulp. With Test 23 the recovery rises slowly at first, then suddenly increases toward completion. The amount of potassium amyl xanthate necessary

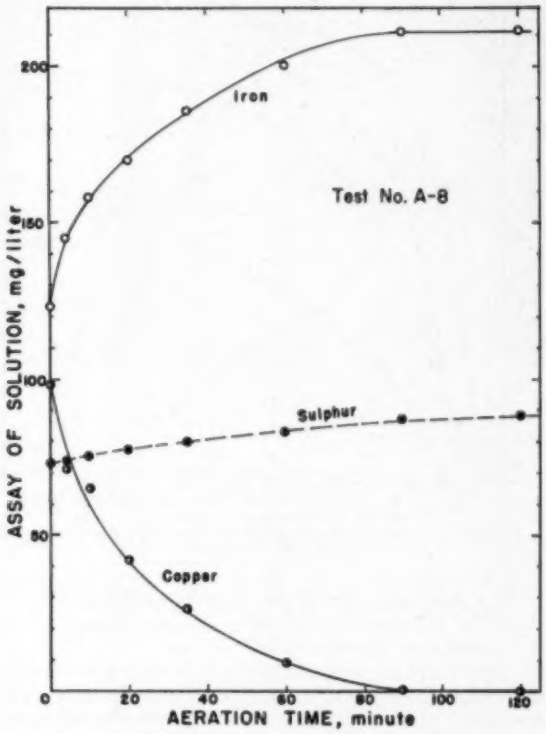


Fig. 7—Aeration test with 6.9 lb $CuCl_2 \cdot 2H_2O$ per ton.

to precipitate Cu^{++} ion roughly corresponds to the projected intersection of the two parts of the curve.

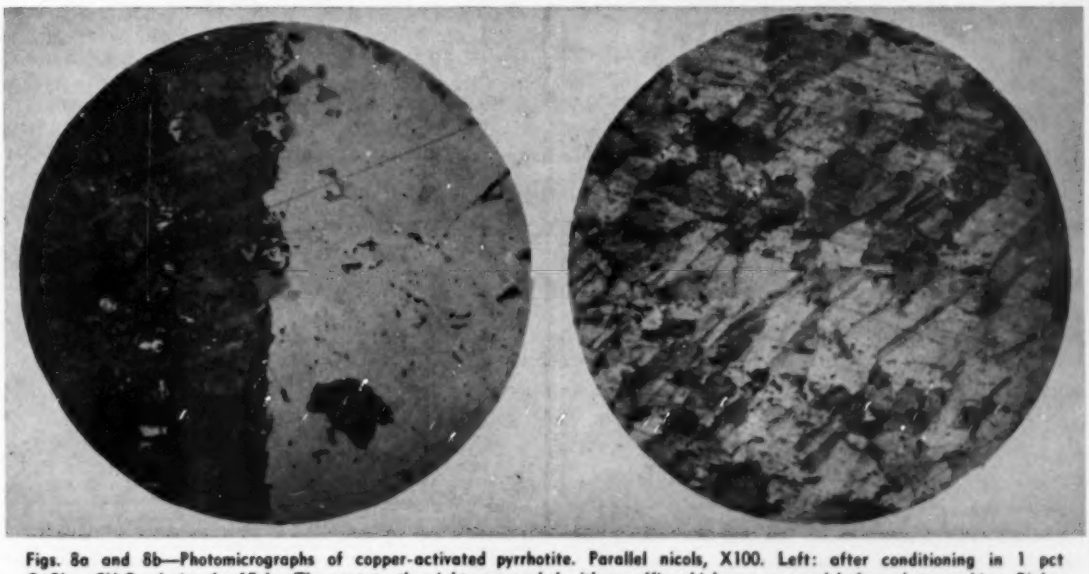
In a separate test the equivalent of 6.4 lb of amyl xanthate per ton was mixed in the cell with a stoichiometric excess of Cu^{++} ion (equivalent to 3.5 lb of cupric chloride per ton) prior to the addition of pyrrhotite. Flotation with this mixture as a collector gave a recovery of approximately 18 pct, presumably due to the independent collecting ability of cuprous xanthate and dixanthogen, and may account for that flotation which takes place prior to the first inflection point.

4—Effect of pH on Unactivated and Activated Flotation: A preliminary flotation experiment at a pH of approximately 2.5 with amyl xanthate indicated that 1 lb of this collector per ton was sufficient to give almost complete recovery. One series of tests was made at this collector addition, and the pH was varied from 2 to 11 by adding hydrochloric acid, sulphuric acid, sodium hydroxide, or calcium hydroxide. Another series was run at an amyl xanthate addition of 6 lb per ton on restricted pH range.

Table III. Analysis of Cu^{++} in Pulp Solution after Activation

Item	Test 22	Test 23	Test 24
$CuCl_2 \cdot 2H_2O$ added	1 lb/ton or 25 mg	5 lb per ton or 125 mg	
Conditioning time	15 min	15 min	2 hr
Excess Cu^{++} in pulp	0.09 mg	17.2 mg	5.0 mg
Equivalent amount of amyl xanthate precipitated by excess Cu^{++}	0.02 lb per ton	4.34 lb per ton	1.25 lb per ton

The collector and the frother were added after 3 min conditioning with acid or with alkali. The pH of the pulp was measured before and after each flotation test. The average of the two values was taken as the pH during flotation. In the first series of tests total iron and sulphur analyses were made on the pulp solution prior to flotation. The results of this experiment are given in Fig. 14. In this figure a *critical pH* is sharply defined at about 4.5, which corresponds roughly to the *equilibrium pH*. Below this pH, flotation recovery is almost complete, while above this value the floatability of pyrrhotite decreases to a minimum. It was observed that at collector addition of 6 lb per ton, there was a tendency to cause over-frothing when the pH was raised beyond the *critical* value even without the benefit of a frother. This increased the amount of material mechanically carried over in the froth and accounted



Figs. 8a and 8b—Photomicrographs of copper-activated pyrrhotite. Parallel nicols, X100. Left: after conditioning in 1 pct $CuCl_2 \cdot 2H_2O$ solution for 15 hr. The part to the right was sealed with paraffin which was removed before photographing. Right: after conditioning in 0.35 pct $CuCl_2 \cdot 2H_2O$ solution for 15 hr. Note the difference in shade of color among the pyrrhotite grains.

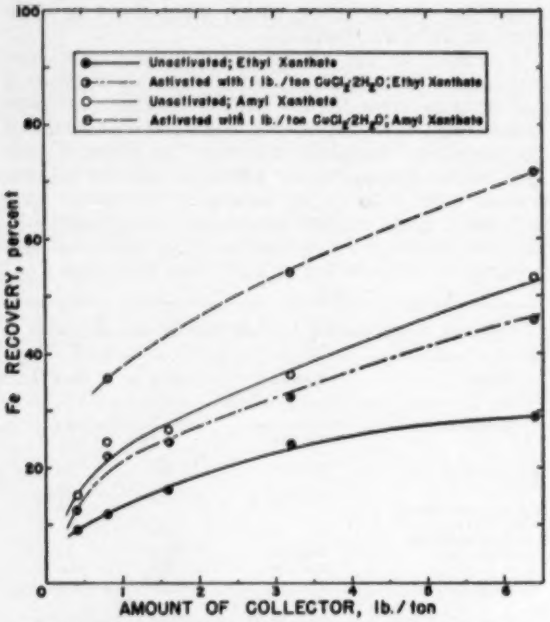

Unactivated; Ethyl Xanthate
Activated with 1 lb./ton $CuCl_2 2H_2O$; Ethyl Xanthate
Unactivated; Amyl Xanthate
Activated with 1 lb./ton $CuCl_2 2H_2O$; Amyl Xanthate
Fe RECOVERY, percent
AMOUNT OF COLLECTOR, lb./ton

Fig. 9—Effect of collector addition on flotation recovery.

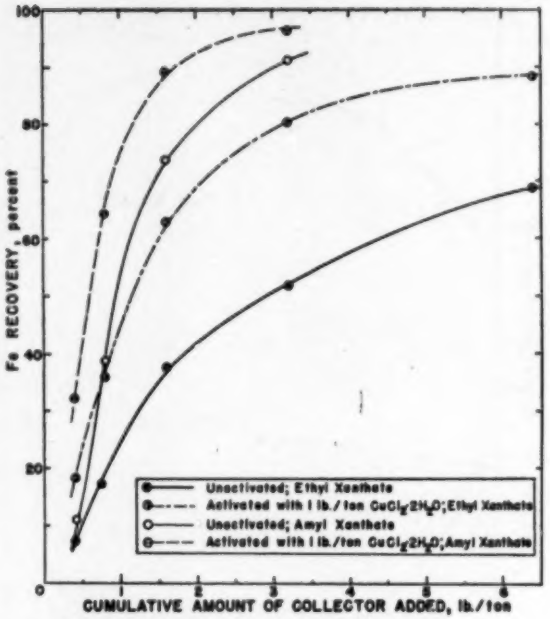

Unactivated; Ethyl Xanthate
Activated with 1 lb./ton $CuCl_2 2H_2O$; Ethyl Xanthate
Unactivated; Amyl Xanthate
Activated with 1 lb./ton $CuCl_2 2H_2O$; Amyl Xanthate
Fe RECOVERY, percent
CUMULATIVE AMOUNT OF COLLECTOR ADDED, lb./ton

Fig. 10—Effect of stage collector addition on recovery.

for the increase in recovery with pH in that range. After the addition of acid or alkali, however, it was also noted that the pH tended to drift toward the *equilibrium* value. For this reason a series of different recoveries was obtained at the critical pH. Taking that recovery obtained with addition of neither acid nor alkali as a reference, acid addition increased and alkali addition decreased the recovery, the increase or decrease depending on the amount of addition. In one instance sufficient acid was added to give a pH of approximately 2. Forty minutes of conditioning restored the pH to the critical and equilibrium value of 4.5, and flotation of this pulp gave the same recovery as when pH was 2, indicating that pH alone may not control floatability.

The analyses of the pulp solution show that the amount of iron increases with the addition of acid below the critical pH, Fig. 14b. The sulphur remains more or less constant throughout the same range, but hydrogen sulphide gas was evolved from

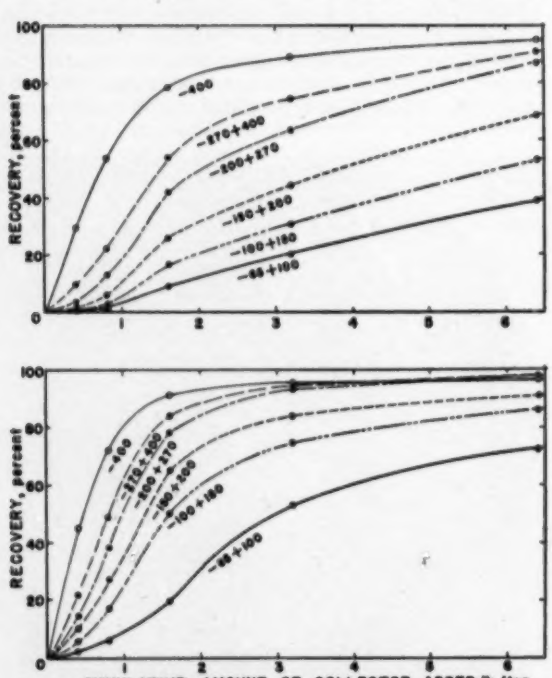


Fig. 11—Size distribution in flotation products obtained by stage addition of ethyl xanthate. Above, inactivated. Below, activated with 1 lb $CuCl_2 \cdot 2H_2O$ per ton.

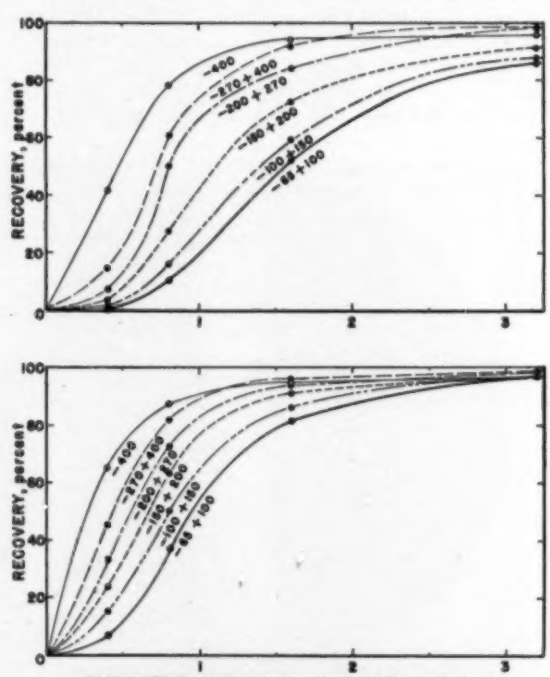


Fig. 12—Size distribution in flotation products obtained by stage addition of amyl xanthate. Above, unactivated. Below, activated with 1 lb $CuCl_2 \cdot 2H_2O$ per ton.

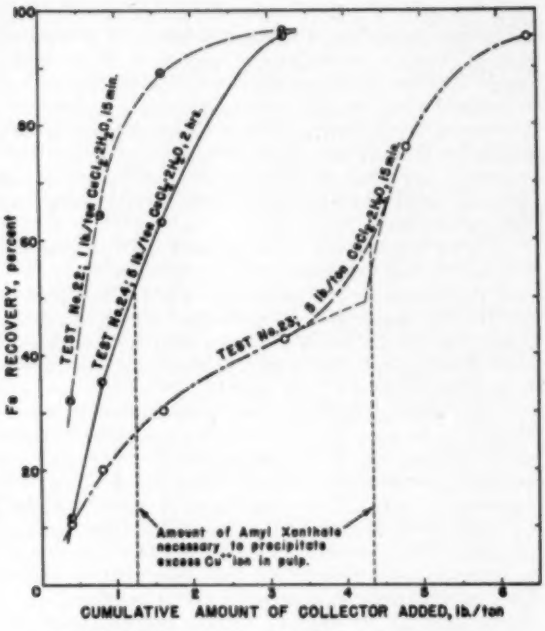

Fe RECOVERY, percent
CUMULATIVE AMOUNT OF COLLECTOR ADDED, lb./ton
TEST No. 22; 1 lb./ton CuCl2·2H2O, 15 min.
TEST No. 24; 6 lb./ton CuCl2·2H2O, 2 hr.
TEST No. 23; 6 lb./ton CuCl2·2H2O, 15 min.
Amount of Amyl Xanthate necessary to precipitate excess Cu++ ion in pulp.

Fig. 13—Detrimental effect of excess Cu^{++} on recovery.

the pulp. This indicates that the acid attacked the pyrrhotite and presumably cleaned the surface. Above the critical pH the amount of sulphur slightly increases with increasing pH, but the iron decreases rapidly to zero at about 7.

The effect of pH on pyrrhotite activated with 1 lb of cupric chloride per ton was also investigated. Fifteen minutes of conditioning was provided for the activation, followed by an additional 3 min of agitation with acid or alkali for pH adjustment. The results of this experiment are given in Fig. 15.

The presence of a critical pH is also indicated in Fig. 15a. The transition between flotation and depression, however, is rather gradual, ranging in pH from 3 to 5. This may be accounted for by the fact that the pH of the pulp containing copper-activated pyrrhotite drifts rather sluggishly toward the equilibrium value after the addition of acid or alkali. It was noted that a recovery of approximately 20 pct was obtained above the critical pH, compared to only 10 pct for the non-activated pyrrhotite at the same collector addition.

5—Effect of Aeration on Flotation: Flotation tests were made by first aerating different pulps with air, oxygen, and nitrogen each for 1 hr. Amyl xanthate, 1.6 lb per ton, was used as collector. The results are given in Table IV.

Table IV. Effect of Aeration on Flotation Recovery and Soluble Ions*

Test No.	Gas Used for Aeration	pH after Aeration	Analysis of Solution before Flotation: Total Fe, Mg Per Liter	Total S, Mg Per Liter	Fe Recovery, Pct
52	Oxygen	4.2	96	106	29.3
53	Air	4.45	110	115	48.9
54	Nitrogen	5.1	138	130	91.3

* Flotation was performed with the same gases used for aeration.

The results show that aeration with air and oxygen reduces the floatability of pyrrhotite. There is no great difference in the amount of iron and sulphur present in the three pulps.

Discussion of Results

Cupric ion is abstracted by pyrrhotite in the presence of air and its depletion from solution is proportional to the increase of iron in the pulp. The resulting activated pyrrhotite ceases to liberate iron and sulphur on further aeration. However, a considerable amount of copper is abstracted from solution in the first 15 sec of agitation. For example, in Fig. 7, 143.5 mg of copper per liter was initially added, but with 15 sec of elapsed time between addition and commencement of aeration, this had decreased in the pulp to 98.0 mg of copper per liter. Disregarding this initial loss, the amount of copper abstracted and the amount of iron liberated in Tests No. A-6, A-7, and A-8 are compared in Table V. The amount of iron in the pulp solution as given in the table is the total *less* the amount found in solution at 15 sec after adding the copper.

Table V. Relation between Copper and Iron in Pulp Solution during Aeration

Item	Test A-6	Test A-7	Test A-8
$CuCl_2 \cdot 2H_2O$ added, lb per ton	0.7	3.4	6.9
Cu abstracted, millimol	0.05	1.73	4.13
Fe liberated, millimol	0.05	1.92	4.35

The results show, within experimental error, the stoichiometric exchange reaction between copper ion and iron atoms at the pyrrhotite surface. Symmetry between the iron and copper curves (Figs. 5, 6, and 7) also suggests this exchange type of reaction.

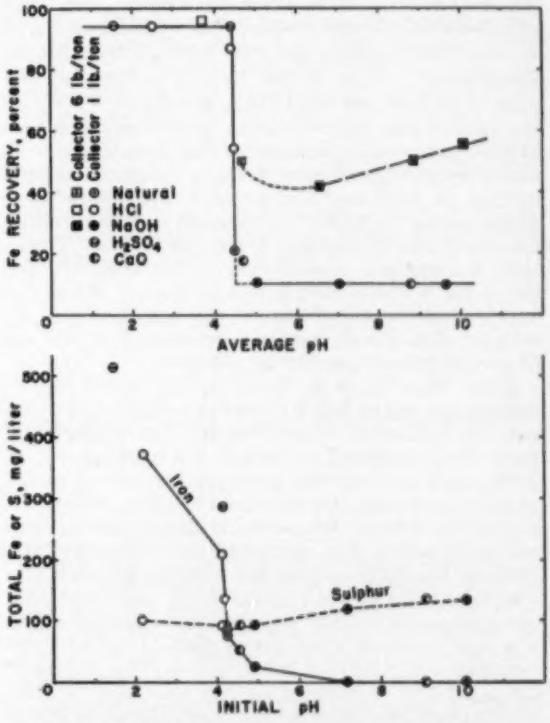


Fig. 14—Effect of pH on flotation recovery and total Fe and S in pulp solution, without activation. (a) flotation recovery, above: frother B-23, .04 lb per ton; collector amyl xanthate. (b) below: analysis of pulp solution before flotation.

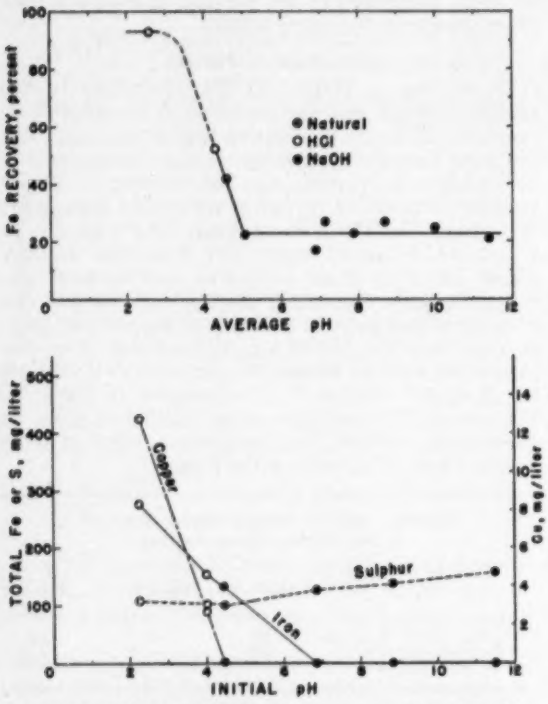


Fig. 15—Effect of pH on flotation recovery and total Fe, S, and Cu in pulp solution, with copper activation. (a) flotation recovery, above: frother B-23, .04 lb per ton; collector amyl xanthate, 1 lb per ton. (b) below: analysis before flotation.

Pyrrhotite has lattice constants of 3.43 A along the a-axis and 5.79 A along the c-axis.[13] The unit cell contains one iron atom in the (0001) plane, two in the $(10\bar{1}0)$ plane, and two in the $(01\bar{1}0)$ plane. Consequently there is one iron atom in a surface area of 10.2 A^2 for the (0001) plane and 9.9 A^2 for the $(10\bar{1}0)$ and $(01\bar{1}0)$ planes. Therefore, each iron atom occupies an average surface area of 10.0 A^2. Since the pyrrhotite sample has a measured specific surface of 3000 cm^2 per g, there are 3×10^{18} iron atoms on the surface of every gram of this material, assuming that the sample is pure pyrrhotite. To obtain a complete monolayer replacement of iron atoms for a 300-g sample would require 254 mg of cupric chloride dihydrate. If the sites occupied by sulphur also adsorb copper, a maximum of 508 mg of cupric chloride would be required.

From Test No. A-8, omitting the initial loss of copper, 707 mg of cupric chloride equivalent of copper are abstracted by pyrrhotite. The replacement has extended beyond formation of a monolayer even if both sulphur and iron sites are considered to abstract copper, and the reaction would be very much beyond monolayer formation if initial loss of copper were taken into consideration. However, this does not take into account the effect of attrition that may take place in the Fagergren cell. An insubstantial increase in sulphur and iron upon further agitation and aeration after completion of replacement indicates that attrition is negligible. The change of the pyrrhotite specimens caused by copper activation in more concentrated solutions, shown in Fig. 8, is indicative of more than monolayer replacement.

The mineral surface is stabilized with the addition of 103 mg of cupric chloride, as shown in Fig. 5. That is, no iron and a negligible amount of sulphur pass into solution with extended aeration. Considering the theoretical minimum amount of 254 mg of cupric chloride required for formation of a monolayer, it is unnecessary to have complete monolayer replacement to stabilize the surface of pyrrhotite.

Several hypotheses have been presented to account for the adverse effect of oxidation of sulphide minerals on their flotation characteristics, but, in general, all of them can be included in the following two categories:

1—The detrimental effect of cations[10,14] or anions[15] formed by the oxidation of the minerals.

2—A change in the surface properties, which will inhibit the adsorption of collector on the mineral. Examples are the formation of a film on the mineral surface by either chemical reaction with, or adsorption of, some ions in the pulp.[16,17]

From the experimental work presented in Table IV, it can be seen that 1 hr of aeration of pyrrhotite with oxygen, air, and nitrogen before flotation resulted in recoveries of 29.3, 48.9, and 91.3 pct respectively, whereas the amounts of total iron and sulphur in the solution were essentially the same in all cases. Unless certain soluble sulphur compounds are detrimental to flotation, the effect of the soluble ions in the pulp can at present be regarded as a minor factor. Therefore, within the scope of the present investigation, differences in the flotation recoveries may be attributed to the formation of a surface film on the mineral. The aeration tests have shown that except for the initial stages, the sulphur increases at higher rate than the iron when oxygen or air is used, while both iron and sulphur increase at the same rate with nitrogen. This lower rate of liberation of iron than of sulphur in the case of air and oxygen aeration is suspected to be due to the precipitation of iron, presumably as ferrous or ferric hydroxide, some of which may coat the mineral surface. In Fig. 14b, the amount of iron in the pulp solution is seen to decrease rapidly with alkali addition, and the depression of pyrrhotite by this addition may be accounted for by the formation of a similar inhibiting coating on the surface.

Flotation tests have sharply defined the critical pH as about 4.5 for pyrrhotite when potassium amyl xanthate is used as collector. Wark,[18] using the contact angle method, reported the critical pH of pyrrhotite to be 6.0 in a solution containing 25 mg per liter of potassium ethyl xanthate. It is interesting to note that Yamada and Muraoka[19] report a critical pH of 4.6 to 5 for Yanahara pyrrhotite with a mixture of camphor blue oil and coal tar as collector.

It has been pointed out previously that the cleanliness of the mineral surface rather than the pH of the pulp may determine the floatability of pyrrhotite. This is further supported by the information given in Table IV. One hour of aeration with nitrogen gave a recovery of 91.3 pct at a pH of 5.1. On the other hand the oxygen-aerated pulp gave only 29.3 pct recovery when the pH was 4.2.

Reviewing the results of this investigation, it has been ascertained that the flotation circuit has to be acidified considerably to get a good recovery of pyrrhotite. However, this may not be practical if the ore contains calcareous minerals. In this case copper activation and stage addition of collector may provide a better solution of the problem.

Conclusions

The results of this investigation lead to the following conclusions.

1—Pyrrhotite in aqueous suspension liberates ferrous ion and soluble sulphur compounds, including sulphate ion.

2—Soluble ions pass into solution upon aeration with air, oxygen, and, after extended aeration, to a lesser extent with nitrogen.

3—A pulp consisting of pyrrhotite in water tends to reach an equilibrium pH.

4—Cupric ion is abstracted by pyrrhotite. The evidence indicates a stoichiometric exchange with iron atoms of the pyrrhotite.

5—A pyrrhotite surface can be stabilized by abstraction of less than a monolayer of copper.

6—Abstraction of copper can be more than is required for formation of a monolayer. The replacement of pyrrhotite by copper seems to be preferential along certain crystallographic directions.

7—Amyl xanthate is superior to ethyl xanthate as a collector for pyrrhotite.

8—Copper activation is beneficial to flotation of pyrrhotite, but excess cupric ion in the pulp is detrimental.

9—Stage addition of collector increases flotation recovery and requires less overall quantity of collector for equivalent recovery.

10—Acid addition greatly increases the floatability of pyrrhotite.

11—Pyrrhotite with potassium amyl xanthate as collector has a critical pH of 4.5. This corresponds roughly to the equilibrium pH obtained by aeration of a pulp containing pyrrhotite.

12—Copper activation is of no particular advantage in flotation beyond the critical pH.

13—Aeration with air and oxygen is detrimental to the flotation of pyrrhotite.

Acknowledgments

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Botanical Methods of Prospecting for Uranium

by Helen L. Cannon

BOTANICAL methods of prospecting for metalliferous ores are based on the premise that deposits at depth may be reflected chemically in surface vegetation. For the past several years, on behalf of the Atomic Energy Commission, the U. S. Geological Survey has investigated on the Colorado Plateau the application of botanical methods to uranium prospecting. Results suggest that orebodies may be found under a considerable cover of barren sandstone through the absorption of uranium and associated trace elements by plants growing at the ground surface.

Plant physiologists have demonstrated that uranium is a necessary nutrient for plant growth and therefore is present in all plants.[1] The amount present is small but measurable. The absorption of uranium by plants growing over ore deposits forms

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the basis, therefore, for a method of prospecting by plant analysis.

Selenium and sulphur, two elements associated with uranium and vanadium in ores of many districts, are necessary in large quantities only to certain groups of plants. These plants, called indicator plants, are present only in soils or rocks containing large amounts of selenium and sulphur and can be mapped to indicate mineralized or geologically favorable ground. The distribution of indicator plants then offers a second tool for uranium prospecting.

Prospecting by Plant Analysis

Absorption of uranium by plants has been studied in connection with the development of botanical methods of prospecting.[5] Uranium is absorbed through the roots of plants, and much of the uranium is precipitated within the cells of the roots and held there; a lesser amount is transported to the branches and leaves. This amount in the branches and leaves is detectable, however, and is sufficient for reconnaissance prospecting. Uranium content varies with the species, time of year, and availability of the metal in the soil. It is rare for the uranium content in the ash of any species growing in nonmineralized sandstone to be greater than one part per million (ppm). A uranium content of several parts per million is common in the ash of plants rooted in ore. Any species of plant can be used in a systematic sampling program if that plant is widely distributed and the roots penetrate to the ore zone. The depth of root penetration differs for any given area with the species of plant and the depth to water. Deep-rooted shrubs and trees of semi-arid regions commonly have root systems 30 to 50 ft in length, and roots have been observed in mines at depths as great as 100 ft.

A basic problem associated with the collection of large numbers of samples is the establishment of a sample type that is uniform, representative, easily procured, and easily handled. Deep-rooted junipers and piñons fulfill these requirements most satisfactorily on the Colorado Plateau, although shadscale and other low shrubs may be used in areas where ground water is not available to vegetation. A composite sample of branch tips or leaves is taken from all sides of the tree and at the same distance aboveground on the tree. A two-man party can collect 50 samples per day spaced at intervals of a few hundred feet. Rapid laboratory methods of analysis, however, have not yet been perfected to handle large numbers of samples on a comparable daily basis. At present the samples are put through an ashing process, a chemical extraction, and finally a fluorimetric analysis using a fluoride-carbonate flux.[6] Samples are collected during the field season for chemical analysis in Survey laboratories during the winter months.

Artificial contamination introduces a considerable source of error in sampling areas of active mining or milling. Dust from an operating surface pit may raise the uranium content of nearby trees from 2 to 100 ppm in the ash. Contamination from the mill at Uravan, Colo., has substantially increased the content of uranium in juniper ash for a distance of several miles. A sampling program on the dune sands in the Carrizo Mountains of Arizona resulted in outlining only the roads used by ore trucks.

The discussion so far has been concerned only with the absorption of uranium from carnotite (potassium uranyl vanadate) deposits occurring in the Colorado Plateau. Uranium is more readily absorbed by plants growing on a carbonate deposit like schroeckingerite (a complex uranyl carbonate-sulphate) than on carnotite. Seven thousand ppm, or seven-tenths of a percent in the ash was found in roots of a greasewood plant growing in a deposit of schroeckingerite in the Red Desert in Wyoming. The uranium content of trees growing on the limestone deposits of Grants, N. M., is large where the deposits have been exposed to weathering. Apparently absorption of uranium by plants is increased in the presence of soluble carbonates.

A plant may be used as an indicator in botanical prospecting if its distribution is controlled by any factor related to the chemistry of the ore deposit. In carnotite districts, the absence of specific groups of plants is as indicative of mineralized ground as the presence of certain others. In arid soils of high salt content, for instance, the common saltbush, sagebrush, and hop sage are scarce or even absent. They are generally replaced by shadscale, turpentine weed, and rabbitbrush. This replacement effects an overall change in the appearance of the flora and is a common characteristic of carnotite districts.

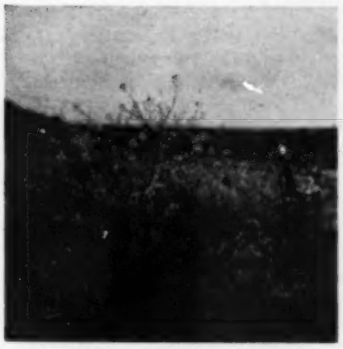
Prospecting by Mapping Indicator Plants

In a specific search for orebodies within a given district, selenium- or sulphur-indicator plants may be very useful. Selenium-indicator plants bear a recognizable relationship to carnotite deposits of the semi-arid Southwest. The various species on and around deposits have distinct distribution patterns, which depend on the amount of selenium in the ore and the amount required by the plant. For this reason some species are more important than others in prospecting for mineralized ground in a given locality. Plants that require large quantities of sulphur were at first ignored in this study. However, recent drilling in the Thompsons district, Utah, has shown them to be useful in indicating ores that contain an appreciable quantity of sulphates. The plants belong generally to three families, lily, mustard, and buckwheat. The same or closely related plants may also be used as indicators of sulphide ores in base-metal districts. Six sulphur-indicator plants are shown in Figs. 1-6.

The onion and Sego-lily, both of the lily family, are very shallow-rooted and therefore are useful only where sulphates have migrated upward into the surface soils. The degree of upward migration in arid soils was demonstrated in the Thompsons district, Utah, where several orebodies at an average depth of 20 ft were discovered under indicative patches of these plants. Desert trumpet, an *Eriogonum* with an inflated stem, is tolerant of high-sulphate clay soils. It is common around gypsiferous uranium ores and has been used in locating wagon-drill holes in some areas. Many other species of *Eriogonum* act as indicator plants near uranium and sulphide ores. Peppergrass and other members of the mustard family are common on near-surface ores. Tumbleweed mustards are abundant around ore deposits on some of the higher mesas. *Stanleya*, or prince's plume, is a mustard that requires both selenium and sulphur for growth.

The selenium-indicator plants require a definite amount of selenium to maintain growth. However, the amount required is known to differ with the different species, and each plant develops a distinctive distribution pattern around a given deposit. Six selenium-indicator plants are shown in Figs.

Sulphur-Indicator Plants Common in Uranium Districts, Figs. 1-6



Sisymbrium altissimum (tumble mustard)

Toxicoscordion gramineum (death camas)

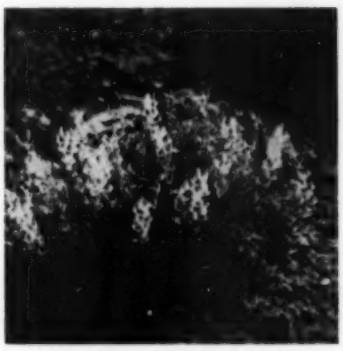
Eriogonum inflatum (desert trumpet)

Lepidium montanum (peppergrass)

Stanleya pinnata (prince's plume)

Allium acuminatum (wild onion)

Selenium-Indicator Plants Common in Uranium Districts, Figs. 7-12



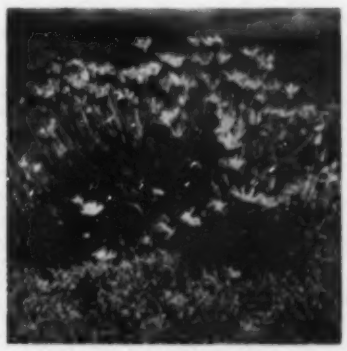
Astragalus confertiflorus (milk vetch)

Astragalus preussi var. arctus (milk vetch)

Astragalus thompsonae (milk vetch)

Astragalus pattersonii (milk vetch)

Oryzopsis hymenoides (ricegrass)



Aster venusta (woody aster)

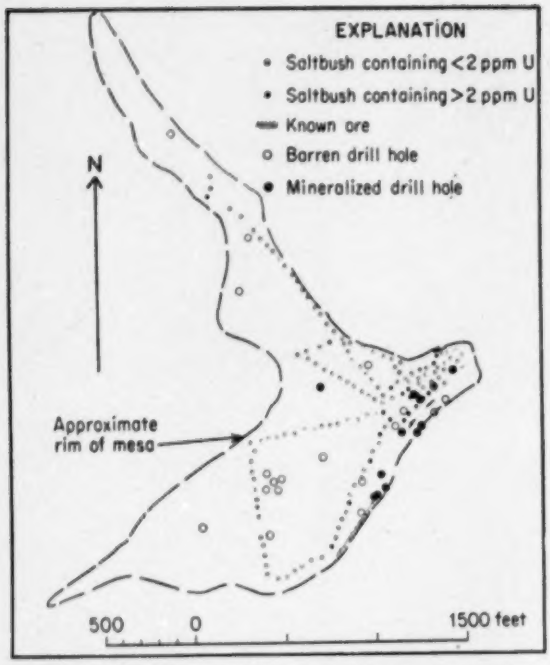


Fig. 13—Sketch map of Yellow Cat mesa, Grand County, Utah, showing distribution of uranium content in saltbush in relation to mineralized ground.

7-12. Woody asters and ricegrass have low selenium requirements and are common on alluvium and dune sands in carnotite districts. Certain species of *Astragalus,* or milk vetch, are the most effective indicators in carnotite districts. The genus is a large one containing hundreds of species, but only certain tribes of them are selenium-absorbers and only a comparatively few species are useful in prospecting. Several of the species are small rosette forms difficult to distinguish or to map on a large scale. *Astragalus thompsonae* with furry pods is one of these. *Astragalus confertiflorus* has blue foliage and grows almost exclusively on blue mudstone, where the plant extracts large quantities of ferrous iron. The selenium requirements for this plant are low, but the plant is useful in prospecting favorable portions of an ore-bearing outcrop. The most useful indicators of uranium deposits are closely related, belong to the same tribe, and are somewhat difficult to tell apart. Two species occurring in the Thompsons district are *Astragalus preussi* and *Astragalus pattersonii.* The flowers of *A. preussi* are pink; and the flowers of *A. pattersonii* are creamy white. *A. pattersonii* grew around 13 holes out of a total of 26 ore holes drilled in the Yellow Cat area in 1952.

Evaluation of Botanical Methods

Prospecting by plant analysis is limited to detecting anomalous material within about 50 ft of ground surface. In a few places, where jointing is well developed, tree roots penetrate sandstone beds 60 to 70 ft thick to reach ground water. Where the ore-bearing bed is also an aquifer, the absorption of uranium by trees is uniform and the resulting uranium values can be contoured.

The accuracy of predicting mineralized ground is of a high order. More than 2 ppm uranium in trees is indicative of geologically favorable ground and usually indicative of mineralized ground. An example is shown in Fig. 13. Several hundred samples of shadscale were collected on a mesa in the Thompsons district. The only botanically favorable ground is in the southeast corner between two known orebodies. Drilling proved the mesa to be barren except in the indicated section, where two orebodies were discovered. During the 1952 field season, more than 3000 samples of juniper and piñon were collected on a bench of the Todilto limestone member of the Wanakah formation near Grants, N. M. The results have been contoured section by section and turned over to the Atomic Energy Commission in advance of drilling. Although the area has not yet been drilled by the Atomic Energy Commission, many of the anomalies which have been explored by private enterprise have been found to be mineralized.

Prospecting by indicator plants has been tested in the Thompsons district, where plants were mapped over an area of 6 sq miles and where 1000 holes were subsequently drilled. A summary of results is shown in Table I. The restriction of indicator plants to geologically favorable ground was found to be an important guide. Of the 194 holes drilled in areas supporting the growth of indicator plants, 90 were in mineralized ground. Indicator plants are present in the vicinity of 12 pct of the unmineralized holes, 54 pct of the mineralized holes (including ore holes), and 81 pct of the ore holes. Four orebodies of the ten discovered in the Yellow Cat area would not have been found by means of the grid pattern of exploration drilling had it not been for the additional information furnished by indicator plants.

Table I. Correlation of Indicator Plants with Mineralized Ground in the Thompsons District, Utah

Item	Unmineralized Holes	Mineralized Holes		Ore Holes		Totals	
		No.	Depth to Ore Horizon, Ft	No.	Depth to Ore, Ft	No.	Depth to Ore Horizon, Ft
Plants present	104	69	44	21	25	194	40
Plants absent	731	70	59	5	37	806	57
Total holes drilled	835	139	53	26	27	1000	49
Ratio of botanically favorable holes to total no. of holes		12 pct		54 pct		81 pct	

Results of drilling demonstrate that holes must be placed with close reference to plant patches and with careful regard for dip, ground-water movement, joint patterns, and other geologic features. In many places several holes were drilled in the vicinity of a plant patch to discover the orebody out of which the selenium had moved. Although the statistical score is imperfect, botanical prospecting is probably a worthwhile tool in the search for uranium and is useful wherever deposits are less than 70 ft from surface and where selenium and uranium are readily available to plant roots.

References

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Flotation Theory: Molecular Interactions Between Frothers and Collectors at Solid-Liquid-Air Interfaces

by J. Leja and J. H. Schulman

FROTH flotation is usually effected by the addition of a collector agent and a frothing agent to an aqueous suspension of suitably comminuted mineral ores. The action of collectors is to adsorb onto the surfaces of minerals to be separated, sensitizing them to bubble adherence. The action of frothers has, in the past, been accepted as that of froth formation only, brought about by a lowering of the air/water interfacial tension. Substances capable of producing froth are classed[1a, b] according to their relative capacities for production of froth-volume and froth stability in the simple frother-water system.

The purpose of this paper is to show that the surface active agents acting as frothers become effective only when there is a suitable degree of molecular interaction taking place between collector molecules and frother molecules at the air/water and solid/water interfaces. Further, the discussion will demonstrate that the actual mechanism of adherence of an air bubble to a suitably collector-coated particle is due to the molecular interaction collector-frother. This leads to the formation of a continuous interfacial film of associated molecules, anchored to the mineral by polar groups of the collector, and enveloping the whole bubble. The tenacity of adhesion mineral-to-bubble results from the strength and the visco-elasticity of this mixed film.

Some 20 years ago Christman[2] postulated mutual dependence of collector and frother in effecting flotation. This view was, however, strongly opposed by Wark,[3] who pointed out that an addition of frother had no effect on the value of contact angle once this was established in the solution of collector. More recent work by Taggart and Hassialis[4] indicated that the presence of frother, namely, cresol, leads to the immediate establishment of a contact angle on sphalerite, partially coated with xanthate, whereas an air bubble fails to make contact in potassium ethyl xanthate solution alone, even after 60 min induction time. Wrobel[5] draws attention to the selectivity of frothers in flotation.

Many instances of antagonistic effects of certain mixtures of frothers (or collectors and frothers) on flotation froth have been known to flotation operators and have been reported in literature. Taggart[6] and Cooke[7] give several examples of incompatibility of certain ratios of frothers and collectors, e.g., oleate and long-chain sulphates, pine oil and soaps.

Monolayer Penetration. Properties of insoluble films produced by molecules of surface active agents orientated at the air/liquid interface are conveniently studied by the Langmuir trough technique, described fully by Adam.[8] Using the trough technique Schulman and Hughes[9] and Schulman et al.[10a, b, c, d, e] established the existence of molecular interactions occurring between certain types of surface active agents. Their experiments revealed the phenomenon of penetration of an insoluble monolayer (e.g., a film of a long-chain alcohol) by a soluble agent (e.g., sodium alkyl sulphate) injected into the substrate (water or salt solution). The degree of molecular interaction taking place on penetration is determined by changes in the surface pressure of the resulting film, changes of its surface potential and its mechanical properties (viscosity and rigidity).

When the interaction takes place between both polar groups and both hydrophobic groups of the two participating amphipathic molecules a molecular complex is formed.

Complexes formed on penetration of the monolayer at interfaces are not necessarily true chemical compounds: they are labile in solution, the activity and reactivity of individual components are greatly different from those of the molecularly associated complex, and on crystallization they usually separate out into components. However, when formed in the orientated state at interfaces they are found to be very stable, although some mixed films spread as monolayers of stoichiometric complexes can show further penetration by subsequent additions of the soluble component injected into the substrate.[10e]

The degree of association between two or more types of surface active agents is very sensitive even to small changes in electric (dipole) moment of the polar groups of the amphipathic molecules as influenced by magnitude and position of neighboring ions or dipoles, their size, concentration, and stereochemistry. In addition, the molecular association is greatly influenced by concentration and type of inorganic salts in the substrate, by its pH, and by temperature. The nonpolar groups of interacting molecules greatly affect the stability of molecular complexes. Progressive shortening of the aliphatic chain of one of the reacting molecules weakens (at an increasing rate) its tendency to form stable complexes. Similarly, introduction of a double bond of cis-form into one of the reacting chains, which changes the straight hydrocarbon chain into a kinked one, or introduction of a branched chain, reduces the stability of the associated complex.

Monolayer Adsorption. Using the trough technique and injecting metal ions into the substrate (water or salt solution) underlying insoluble films of fatty acids, alkyl amines, and sulphates, Wolstenholme and Schulman[11a, b, c] and Thomas and Schulman[12] have established conditions, namely, pH, concentration, and steric factors, under which molecular interactions take place between the *polar groups* of the surface active agents and the *metal ions.* These interactions are marked by great changes in the solubility and mechanical properties of the monolayer of the agent; no surface pressure increases are observed as in monolayer penetration experiments. The results of these adsorption studies, correlated with flotation experiments, indicated that in the case of fatty acids and alkyl sulphates their adsorption onto minerals of base-metals takes place by a similar

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mechanism. Flotation of these minerals occurs whenever the pH and the size of metal ions available at the mineral surface enables the formation of an insoluble film of the *basic-metal soap*. The films of the agents are solidified by the adsorption process owing to hydrogen bonding between the adlineated hydroxyl groups of basic-metal ions; the van der Waals forces between *widely spaced* hydrophobic groups are negligible.

Experimental procedure was based on: (a) interactions between an insoluble alcohol or sulphate monolayer, short-chain homologues of which are used as frothers, spread on the Langmuir trough, and a xanthate (typical collector) injected into the substrate; (b) determinations of the amount of frother abstracted from solution by mineral particles coated with collector; (c) measurements of contact angles formed by air bubbles and insoluble oils on solid surfaces in collector solutions; and (d) frothing and flotation tests using equivalent additions of collectors and frothers.

All reagents used in experiments were of high purity; they were either made and purified in the laboratory (xanthates, oleic acid, alkyl sulphates and sulphonates, alkyl amine hydrochlorides, and substituted amines) or were high-purity commercial products (alcohols). The latter were checked for impurities, capable of adsorption on solids, by contact angle testing on a highly reactive surface of electrolytically polished copper. Only those alcohols were used which did not develop any contact angle, i.e., which contained no impurities of collector-type.

(a) Trough interactions. It can be readily shown that by monolayer penetration of long-chain alcohol films by long-chain xanthates, strong molecular associations exist between these two types of compounds. If a monolayer of hexadecyl alcohol (cetyl alcohol, C_{16} H_{33} OH) is spread on N/100 KCl solution at pH 11 and is held at a constant area and at a surface pressure of 10 dynes per cm, and ½ mg of potassium lauryl xanthate (C_{12} H_{25} xanthate) is then injected into the underlying solution of 400 cc, *an immediate rise of surface pressure of the alcohol film from 10 dynes per cm to 52 dynes per cm takes place,* although the potassium lauryl xanthate solution itself shows initially only 5 dynes per cm surface pressure. This surface pressure of the free lauryl xanthate monolayer, initially equal to 5 dynes per cm, decays to zero pressure rapidly owing to the oxidation of xanthate into dixanthogen molecules, which form only unstable films on their own. The mixed monolayer alcohol-xanthate *remains stable* to very high surface pressures, e.g., 52 dynes per cm. This indicates that the *penetrated alcohol-xanthate monolayer stabilizes the xanthate against oxidation.*

Weak penetrations can still be observed with amyl xanthate (C_5) into cetyl (C_{16}) alcohol monolayers. This type of association would show up more readily with surface potential measurements. The cetyl alcohol film is liquid but on penetration by lauryl xanthate is immediately solidified.

Penetration of a long-chain sulphate monolayer by lauryl xanthate is much weaker than alcohol-xanthate penetration. An increase in surface pressure up to 25 dynes per cm, with 2 mg per 400 cc, takes place with a sodium behenyl sulphate monolayer (C_{22} H_{45} SO_4 Na). Like the cetyl alcohol-xanthate monolayer, the behenyl sulphate-xanthate monolayer is solidified, but much more slowly.

These experiments show that the long-chain xanthates are much more reactive to long-chain alcohols than to the equivalent long-chain sulphates.

(b) Abstraction of Frothers by Collector-Coated Solid Particles (Table I). Procedure: A quantity of air-atomized Cu powder or pure mineral particles was shaken in a cylinder with a solution of collector. Then a solution of frother was added either directly to the cylinder or after prior removal of collector solution by decantation. Comparative determinations of suitable dilutions of frother with distilled water alone, the collector solution, and the residual solution in the cylinder indicated the amounts of frother abstracted by collector-coated particles. Blank determinations for abstraction of frother by solid particles not coated by collector were carried out and showed negligible amounts of abstraction.

Colorimetric methods of analysis for aliphatic alcohols and cresols were adapted from Snell.[13] α Terpineol was determined by the intensity of the colored compound given with salicylic aldehyde, in 66 pct H_2 SO_4 solution; cresols, by the colored compounds given with diazotized sulphanilic acid in NaOH solution. Intensities of color were compared using a Spekker absorptionmeter. With the very low concentrations of frothers used in flotation, extreme care is required in analytical procedure to get reliable and reproducible results. In addition, steps must be taken to avoid interference due either to collector itself or to the products of collector decomposition. Xanthates decompose initially to dixanthogens and finally to alcohols and carbon disulphide. Determinations of alkyl alcohol abstraction cannot, therefore, be reliably carried out in systems containing xanthates. Cresols can be determined only when excess xanthate is removed prior to conditioning with frother.

Determinations of long-chain sulphates and sulphonates were carried out by the partition titration (in chloroform-water) with cetyl trimethyl ammonium bromide (CTAB), using methylene blue as an indicator. The partition titration of long-chain anionic compounds with cationic salts was developed by Hartley and Runnicles[14] and Epton.[15] Owing to hydrolysis of alkyl sulphates only sulphonates could be used in abstraction tests of xanthate-coated solids.

Determinations of frother abstraction were reproducible to 1/10 to 1/5 of *the amount abstracted.* Accuracy of the analytical methods was of the order of 0.001 mg per ml for cresols, 0.01 mg per ml for α Terpineol, 0.005 mg per ml for sodium dodecyl sulphonate.

Abstraction results: Cuming and Schulman[16] have found that adsorption of sodium dodecyl sulphate onto copper powder is possible in the narrow range of pH 5.5 to 9.0 where the insoluble basic copper sulphate soap (C_{12} H_{25} SO_4 (OH) Cu) is formed. In the more alkaline solution the surface of Cu powder is incapable of adsorbing sulphate, but xanthates are still strongly adsorbed.

Sulphonates and sulphates behave similarly in flotation of Cu powder. The alkyl sulphonate gives excellent flotation of Cu at pH 5.5 to 9.0, acting both as a collector and frother, but once the pH is increased above 9.0 the sulphonate starts desorbing, leaving Cu powder completely *hydrophilic.*

Sulphonate concentrated in solution gives excessive but barren froth. If xanthate is now added to the system containing Cu powder and sulphonate at pH > 9, say pH 12.5, it adsorbs immediately on Cu powder and excellent flotation is again effected. At the same time the excessive, barren froth of sulphonate evident in absence of xanthate is replaced by a well-mineralized, relatively stable froth.

Tests 1 and 2 of Table I show that Cu powder

coated by potassium amyl xanthate (KAX) abstracts molecules of sodium dodecyl sulphonate ($C_{12}H_{25}SO_3Na$) at pH 12.5. The blank for abstraction of sulphonate by Cu powder, not sensitized by xanthate-coating, was nil under the same conditions. It can be seen that in test 1 the initial concentration of sulphonate has been reduced by 18 pct, equal to 0.490 mg sulphonate abstracted by 50 g of −300 mesh Cu powder. Test 2 showed 27 pct reduction of initial concentration, equal to 0.387 mg abstracted by 50 g of −100 +200 mesh Cu powder.

Notwithstanding the longer time of conditioning with both collector and frother, the abstraction of sulphonate is lower in test 2 than in test 1, owing to the smaller area of particles: ca 80 cm^2 per g for −100 +200 mesh, and ca 400 cm^2 per g for −300 mesh Cu powder.[17]

Tests 3 and 4 refer to the abstraction of p-cresol by Cu powder sensitized with dodecyl sulphonate at pH 7.5. Although sulphonate acts at this pH as both collector and frother, once the sulphonate remaining in solution and acting as frother is decanted, the floatability of sulphonate-coated particles in distilled water is negligible, unless a frother such as cresol is added. The froth produced by cresol is less voluminous and more brittle than the excessive, tough froth due to sulphonate itself, but the flotation recovery of Cu is not affected. Comparison of tests 3 and 4 shows the effect of time on the degree of p-cresol abstraction, under similar conditions. It is seen that the abstraction of p-cresol continued to increase with the time of conditioning. This effect of time is an indication of a relatively slow rate of molecular association of sulphonate and p-cresol.

Tests 5 and 6 show that abstraction of cresols does take place even when a short-chain xanthate (potassium ethyl xanthate) is employed as collector. Further, they indicate that the amounts abstracted vary by a factor of 10 at least, depending on initial concentrations of collector and frother and the surface area of particles.

Test 8 shows that with reagents which are known to give strong complexes in stoichiometric ratio the

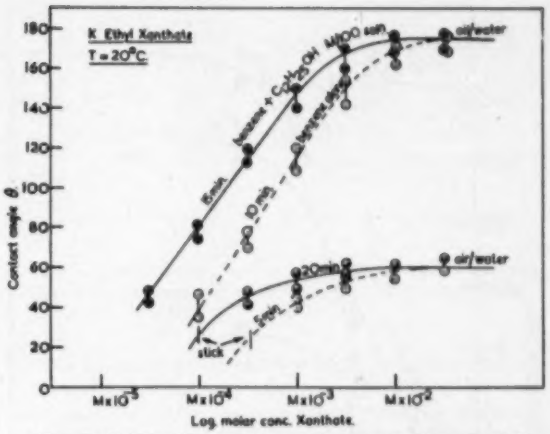

Fig. 1—Relationship: contact angle-concentration of ethyl xanthate on electrically polished copper surface; pH 8.6, temp. 20°C; effects of time of conditioning and of presence of complexing alcohol in the oil phase.

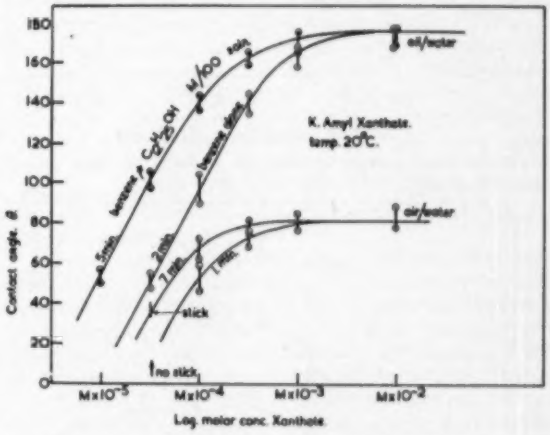

Fig. 2—Contact angle-concentration of amyl xanthate (conditions as in Fig. 1).

Table I. Results of Analytical Determinations of Abstractions of Frothers. Temperature 20°C ± 2°

Test No.	Material	Collector			Frother			pH	Abstraction of Frother	
		Compound	Conc.	Time of Cond.	Compound	Conc.	Time of Cond.		Amount Abstracted	Initial Frother Conc., Pct
1	50g of −300 mesh Cu (a)	KAX (c)	M/1300 2:1 S:W	15 min	$C_{12}H_{25}SO_3Na$	M/7500 2:1 S:W final 1:1 S:W	10 min (c)	12.5	0.490 mg per 50g Cu	18
2	50g of −100 + 200 mesh Cu (a)	KAX (c)	M/10000 2:1 S:W	2 hr	$C_{12}H_{25}SO_3Na$	M/10000 2:1 S:W final 1:1 S:W	1 hr (c)	12.5	0.387 mg per 50g	27
3	50g −300 mesh Cu (a)	$C_{12}H_{25}SO_3Na$ (c)	M/2500 1:1 S:W 26 pct ads	10 min (d)	p-cresol	M/2500 1:1 S:W	10 min (c)	7.5	0.450 mg per 50g	21
4	50g −300 mesh Cu (a)	$C_{12}H_{25}SO_3Na$ (c)	M/2500 1:1 S:W 28 pct ads	10 min (d)	p-cresol	M/2500 1:1 S:W	5 hr (c)	7.5	0.685 mg per 50g	31
5	20g PbS, −60 +200 mesh	KEX	M/20000 1:1 S:W	30 min	o-cresol	M/20000 final 1:2.5 S:W	10 min cell test	7.5	0.056 mg per 20g	22
6	50g ZnS −60 +100 mesh (b)	KEX (c)	M/12500 1:1 S:W	10 min (d)	o-cresol	M/1250 1:1 S:W	2 hr (c)	7.5	1.54 mg per 50g	35
7	30g $BaSO_4$ −120 + 300 mesh	$C_{12}H_{25}SO_3Na$ (c)	M/10000 1:1 S:W 36 pct ads	15 min (d)	αTerpineol	M/5000 1:2 S:W	4 hr (c)	8.0	2.2 mg per 30g	35
8	50g Cu −300 (a)	$C_{12}H_{25}SO_3Na$ (c)	M/1000 1:1 S:W 46 pct ads	20 min (d)	CTAB	M/10000 1:1 S:W	15 min (c)	7.0	1.092 mg per	48

(a) air atomized Cu powder
(b) sphalerite containing 3.1 pct Cu_2S and 15 pct pyrite
(c) cylinder test
(d) solution of collector decanted

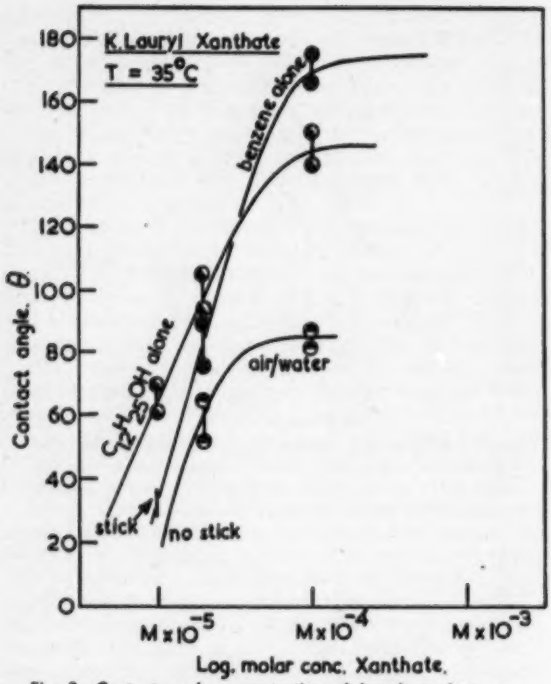

Fig. 3—Contact angle-concentration of lauryl xanthate, on copper surface, pH 8.6; effect of polarity of oil.

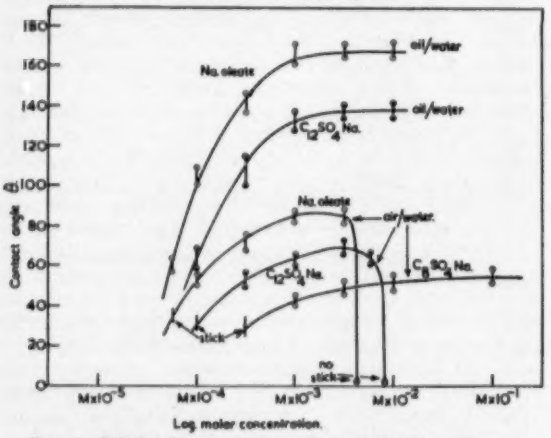

Fig. 4—Relationship: contact angle-concentration of carboxylic soaps and alkyl sulphate, on cleaved $BaSO_4$ surface; pH 12.0, temp. 20°C, conditioning time 5 to 10 min.

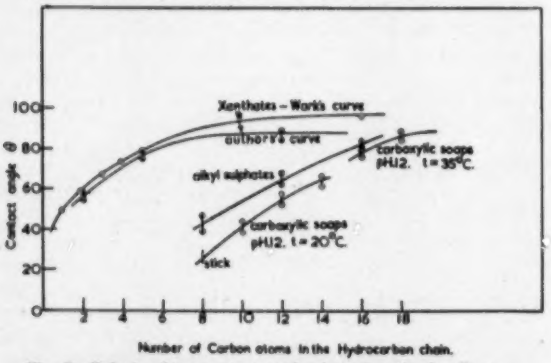

Fig. 5—Relationship: contact angle-chain length of collector, for M/1000 solutions; pH 12.0 for carboxylic soaps, pH 8 to 12 xanthates and alkyl sulphates, temp. 20°C (and 35°C), conditioning time 5 to 10 min.

abstraction proceeds to give nearly a 1:1 relation between collector coverage and frother abstraction. As equimolar concentrations of collector and frother were used, the comparison may be made directly on percentage of initial concentration removed by particles: 46 pct of adsorbed sulphonate abstracted 48 pct of CTAB. Test 7 indicates that the ratio for α Terpineol : sulphonate is nearly 2:1; 35 pct of M/5000 α Terpineol solution was abstracted by 36 pct of M/10000 adsorbed sulphonate.

(c) Contact Angle Measurements. Procedure: A horizontal telescope equipped with cross wires and protractor was used; contact angles were always measured across the water phase. In addition to air bubbles, drops of various oils such as benzene, alcohols, and nujol were also employed. The usual experimental precautions of cleaning the glassware in chromic-sulphuric acid mixture and carrying out blank determinations in distilled water were observed. The contact angle could be measured with the accuracy of ± 1°, but owing to hysteresis, the angles varied by 5° to 10°.

Solid surfaces used for contact angle measurements consisted of freshly electrolytically polished specimens of copper bar (anodic polishing in 55 pct H_3PO_4 solution) and freshly cleaved faces of $BaSO_4$ crystals. Conditions for measurements were standardized with regard to time of conditioning, time of bubble-contact, and *aging* of the reactive surfaces.

Figs. 1 to 6 and Table II. Fig. 1 shows the effects of the concentration, the time of conditioning, and the presence of an alcohol in the oil phase on the development of contact angles between the air/water and oil/water interfaces and the solid surface of electrolytically polished copper metal specimen for potassium ethyl xanthate (KEX). It is seen that for 5 min conditioning time the air/water/solid contact angle can be at first detected as a pronounced *stick* of the air bubble (at concentration of 0.5×10^{-5} KEX), and then progressively increases to a maximum of 60°, with the rise in concentration. For 20 min conditioning time, the development of contact angle starts at a much lower concentration, viz, M x 10^{-4}, and the maximum of 60° is reached sooner. The oil/water/solid contact angles (using pure benzene as the oil phase) can be detected at much lower concentrations of xanthate than those required for air/water contact angle development. At the same concentrations of KEX, the oil/water/solid contact angles are much higher in value than the air/water/solid ones and reach the maximum of nearly 180°, i.e., the benzene drop spreads nearly completely on the xanthate covering the solid surface. If instead of a benzene drop, a drop of M/100 solution of lauryl alcohol (C_{12} H_{25} OH) in benzene is used, the contact angles developed at equal concentrations of xanthate are still higher than those for benzene alone, and the rate of adsorption is much greater.

These curves show clearly that the development of the contact angle depends on the combined effects of the concentration of xanthate and the time of conditioning. These in turn *govern the density of adsorption* of xanthate molecules onto the solid, i.e., the collector coverage. Further, it is shown that the effect of a complexing agent, alcohol, is evident only when collector *diffusely covers* solid surface.

Fig. 2 shows that a similar relationship exists for potassium amyl xanthate; the range of concentrations for which the contact starts to develop is lower than in the case of potassium ethyl xanthate, the maximum of the air/water/solid contact angle is

higher, viz, 80° to 82°, but the maximum of the oil/water/solid is the same as for potassium ethyl xanthate.

Fig. 3 shows the same characteristic developments of contact angles for potassium lauryl xanthate, at still lower concentrations than for potassium ethyl xanthate, and with a still higher maximum of the air/water/solid contact angle. In addition, the relationship between the concentration of lauryl xanthate and the contact angles developed by a drop of lauryl alcohol alone is also shown. It is seen that when the surface of copper is sparsely covered by lauryl xanthate molecules (i.e., in concentrations lower than 0.5 M x 10^{-4}) the drop of alcohol develops higher contact angles than the drop of benzene; at higher concentrations of xanthate, the maximum contact angle is, however, only 145° for alcohol alone, whereas with benzene it is 180°. This behavior indicates that with the partly-hydrophobic surface, diffusely covered by xanthate molecules, the complexing molecules of alcohol can penetrate the diffuse monolayer and thus increase the hydrophobic character of the surface. However, once the full coverage is attained by the collector molecules themselves the penetration is prevented, and the polarity of alcohol molecules in relation to benzene is demonstrated by the differences in contact angles.

Fig. 4 shows the relationship between contact angles on Ba SO_4 crystal faces and concentration of collectors: sodium oleate (cis $CH_3(CH_2)_7CH = CH(CH_2)_7COONa$), sodium dodecyl sulphate ($C_{12}H_{25}SO_4Na$), and sodium octyl sulphate ($C_8H_{17}SO_4Na$).* These types of surface active agents (i.e., carboxylic acids and their soaps, alkyl sulphates, also alkyl sulphonates, alkyl amines and their salts) are capable of adsorption as orientated molecular films, at both the solid surfaces and the air/liquid interface. They are referred to, for flotation purposes, as collector-frother agents. Xanthates (as well as dithiophosphates and dithiocarbamates) adsorb at the air/liquid interface but are immediately oxidized to insoluble dixanthogens, which consequently do not froth. The surface active agents of the collector-frother type are not appreciably affected by oxidation, but they *associate into micelles of hydrophilic character* at high concentrations. For particular polar groups the longer the chain of the surface active agents the lower is the critical concentration (C.M.C.) for micelle formation. It is important to bear in mind that this C.M.C. is influenced by solutions of inorganic salts.

* Further data on contact angles for other soaps and sulphates may be found in the authors' paper: Control of contact angles at the oil/water/solid interfaces in relation to emulsions stabilized by solid particles. *Trans. Faraday Soc.*, 1954.

Table II. Effect of Di-carboxylic Soaps on Ba SO_4

Soap M/1000 sol[a]	pH	Contact Angle: Air/Water	Contact Angle: Benzene/Water	Flotation Tests in Pneumatic Cell
Na-azelaate $Na^+ {}^-OOCC_7H_{11}COO^-Na^+$	7 to 12	No sticking	No sticking	No flotation
Na thapsate	7.0	Slight sticking	40° to 45°	Very good flotation
$Na^+ {}^-OOC C_{14}$	9.0	Good sticking	60° to 65°	
$H_{28}COO^-Na^+$	12.0	Very good sticking but impossible to detach a free air bubble	75° to 80°	

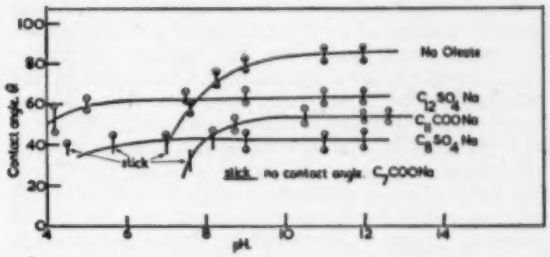

Fig. 6—Relationship: contact angle-pH; M/1000 solutions of carboxylic soaps and sulphates; temp. 20°C, conditioning time 5 to 10 min.

The immediate effect in flotation of the formation of micelles by carboxylic soaps, alkyl sulphates, and also amines is the nonadherence of air bubbles to the solid surface coated by these agents in solutions of high concentrations. The proof that the surface is then still coated by the surface active agent is furnished by the development of full contact angles at the oil/water/solid interfaces. Oil is capable of penetrating the physically bound hydrophilic double layer on the solid and gives as high a contact angle as the fully hydrophobic single layer. These effects are shown in Fig. 4 for Na oleate and Na dodecyl sulphate. The short-chain sodium octyl sulphate ($C_8H_{17}SO_4Na$) shows a comparatively weak tendency for association, and its critical micelle concentration is higher than M x 10^{-1}, but sodium dodecyl sulphate and sodium oleate form micelles at concentrations less than M x 10^{-2}.

Figs. 5 and 6 show the effects of the length of chain and pH on the contact angles at the air/water/solid interfaces. From Fig. 5 it is apparent that for a given concentration of the reagent it is not only the length of chain itself but also the nature of the polar group (sulphate, xanthate, or carboxyl) that determines the magnitude of the contact angles developed with solids capable of adsorbing the reagent.

As is well known, the same agent adsorbed on different solid surfaces gives the same maximum values of contact angles.

Table II shows the results of adsorption on Ba SO_4 crystal of di-carboxylic soaps having a carboxylic group at each end of the hydrocarbon chain. It is evident that adsorption of the di-carboxylic soap takes place through both polar groups as on a water surface; otherwise, if only one group were adsorbing, the other polar group sticking outwards would give a hydrophilic character to the coating, regardless of the length of the hydrocarbon chain. However, in the case of azelaate (C_9) the length of the chain is insufficient to give effective association with frother molecules, whereas the much longer hydrocarbon chain (C_{28}) of thapsate is sufficient to give stronger association with nonpolar groups of its own molecules, or of frother, to effect excellent flotation.

(d) Frothing and Flotation Tests. Procedure: Effects of additions of collectors on the froth-volume of frothers were studied in a frothing setup similar to one used by Sun.[18] Flotation tests were conducted in a 100-ml all-glass cell with a sintered disc partition, aerated by compressed nitrogen. Rate of aeration was measured by a flowmeter and was kept constant for a series of tests. Homogeneous solid particles, air atomized Cu powder, ground galena, sphalerite, and barytes, were used at 1:4 S:W (solid:water ratio).

Results of frothing tests are shown in Tables III and IV and, for straight-chain alcohols, in Fig. 7.

The froth of individual alcohols used as frothing agents is greatly affected by the addition of xanthates, the effect being shown by the variation of froth-volume and by the changes in the character of the resultant froth. The results show that when a constant amount of ethyl or amyl xanthate is added the froth volume at first decreases and then increases, with increasing chain length of alcohol, see Fig. 7. The detailed tracing of effects of frothing of mixtures is complicated by the simultaneous changes in the character of the froth. However, the order of magnitude of the effect of xanthate additions on the frothability of alcohols is similar to that of the increase of the surface pressure obtained in penetration experiments on the Langmuir trough, which are attributed to molecular interactions. This suggests

Table III. Effect of Collector (Xanthate) Addition onto Froth-Volume (Height of Froth in mm ± 5) of Frother*

Concentration of Frother	Initial Frother Volume	Final Froth Volumes with Collectors (40 ml soln) KEX	KAX	K Lauryl Xanthate
	20 ml	alone	alone	alone
—	—	10.1	15.f	20.F
M/1000 iso-butyl alcohol	20.f	10v.f	25v.f	nil
M/1000 2 methyl 2 butanol	35.m	30.m	68v.f	nil
M/1000 4 methyl 2 pentanol	70.l	75.m	86v.f	70.F
M/1000 2 ethyl hexanol	65.m	10.m	95v.f	90.F
M/1000 methyl monyl carbinol	20.1	5.m	25.f	nil
M/1000 phenol	15v.f	20.1	25.m	nil
M/1000 o-cresol	40.f	25.m	65v.f	nil
M/1000 m-cresol	45.f	30.m	50v.f	10.F
M/1000 p-cresol	45.f	35.m	70.f	nil
M/1000 cyclo-hexanol	45.m	35.f	50.f	nil
M/1000 o-methyl cyclo hexanol	55.m	60.f	68v.f	nil
M/1000 p-methyl cyclo hexanol	65.m	75.m	90 foam	nil
M/1000 α-Terpineol	55.m	85.m	95.m	60.F
M/1000 ($C_{12}H_{25}SO_4Na$) sodium dodecyl sulphate	200—350 l&m	350—400.m	400—500.m	140—170.F

* 20 ml frother and 20 ml of xanthate, both M/1000 solutions; const. aeration by nitrogen, temp. 18° to 20°C, pH neutral, time 5 to 10 min; diam of frothing cylinder 42 mm.
Character of froth:
v.f. very fine bubble froth
m. medium size, approximately ¼ to ½ in. diam
l. large size, above ½ in. diam
f. fine bubbles, below approximately ¼ in. diam
F. foam, air dispersed in solution

that molecular interactions are also operative in the frothing phenomena. The analogy is not complete, as in the frothing tests the experimenter is almost certainly dealing with non-condensed films; in Langmuir trough experiments the films are condensed.

Comparison of the effects of straight chain with branched chain and substituted cyclic alcohols, which are known to change the type of molecular association leading to less condensed films, indicates that condensation of interfacial films deters frothing.

The most interesting examples of the effects of stereochemistry and polarity of associating components on frothability are those given by systems dodecyl sulphate: cetyl trimethylammonium bromide (C.T.A.B.) and dodecyl sulphate—dodecylamine hydrochloride, Table IV. Although dodecyl sulphate and C.T.A.B. react strongly to give a 1:1 complex resulting in a formation of a visible precipitate, the size of the bulky polar group $N(CH_3)_3^+$ is such that the resultant $SO_4^-:N(CH_3)_3^+$ grouping of the complex possesses residual polarity which enables the complex to orientate itself preferentially and to spread at the air/water interface (instead of remaining as precipitate in solution) once aeration is started. This tendency leads to the formation of a strong, liquid condensed, non-solidified film, giving tenaceous, stable cellular froth. On the other hand, the interaction between $C_{12}H_{25}SO_4^-$ and $C_{12}H_{25}NH_3^+$, which leads also to a 1:1 complex, gives a visible solidified, strongly hydrophobic film at the interface, too brittle to withstand any vibration, and the solution is incapable of frothing.

Table IV. Examples of Frothing of Collector-Frother Reagents*

Reagents	Frothing	Remarks
$C_{12}H_{25}SO_4Na$	200 to 350 with large air "holes"	comparatively stable (2 to 5 min)
CTAB	400 to 500 with large air "holes"	comparatively stable
$C_{12}H_{25}SO_4Na$ + CTAB	>> 500 in spite of visible precipitation occurring on mixing the two reagents	"honey-comb" structure, stable froth of large size, practically without water
$C_{12}H_{25}SO_4Na + C_{12}H_{25}NH_3Cl$	nil	no precipitate but visible brittle film found on air-liquid interface
$C_{12}H_{25}SO_4Na + C_6H_{17}OH$	250 to 280, foamlike	comparatively stable
$C_{12}H_{25}SO_4Na + C_2-C_5OH$	350 to 500, foamlike	less stable than with $C_6H_{17}OH$
$C_{12}H_{25}SO_4Na$ + α Terpineol	300, foamlike	very stable (for more than 15 min)

* 20 ml of M/1000 solutions used, temp. 18° to 20°C, time 5 to 10 min, pH neutral; height of froth in mm ±3, diam of frothing cylinder 42 mm.

Characteristics of the froth required in flotation cannot yet be described in quantitative terms. The required froth is spoken of as copious, neither too brittle nor too tough. These requirements are in some way related to the type of film produced by molecular interactions between orientated molecules at the air/water interface.

Correct molecular associations between frother and collector molecules must be suitably balanced to give appropriate mechanical properties to the air/water interface.

Results of recoveries obtained by floating galena in a pneumatic cell, using equivalent amounts of frothers and collectors, are presented in Table V. These results show the same characteristic effect

Table V. Flotation Tests in Pneumatic Cell*

Frother	Recovery, Pct KEX	KAX	Remarks
M/100 C_3H_7OH	14.5	—	gradual increase in volume and stability of frothing and mineralization, giving an easily overflowing froth for $C > 6$
M/100 C_4H_9OH	32.0	—	
M/1000 $C_5H_{11}OH$	52.5	66.5	
M/1000 $C_6H_{13}OH$	65.0	74.5	
M/1000 $C_7H_{15}OH$	72.5	83.0	
M/1000 $C_8H_{17}OH$	76.0	85.5	
M/1000 4 methyl 2 pentanol	71.5	80.0	good froth, brittle
M/1000 2 ethyl hexanol	86.5	97.5	copious, good consistency froth
M/1000 methyl nonyl carbinol	51.0	37.5	good mineralization, tough foam
M/1000 o-cresol	55.0	86.5	poor frothing though good mineralization of bubbles
M/1000 m-cresol	64.0	84.5	
M/1000 p-cresol	69.0	82.0	
M/1000 α Terpineol	88.5	98.0	abundant, good consistency frothing

* Using 20 g galena −60 +180 mesh, 60 ml distilled water, 10 ml frother solution, and 10 ml M/1000 xanthate solution. pH 7.5, 1 min conditioning time without aeration, 3 min flotation time using compressed N_2 for aeration.

of progressively increasing molecular associations xanthate-alcohols, leading to higher recoveries, which subsequently drop off when associations are too strong and condensed brittle films incapable of withstanding vibrations are formed. Suitable choice

of branched chains and/or substitution of CH_3 and OH groups in cyclic chains are extremely effective in giving better recoveries. The effects on frothing of frother-xanthate mixtures are, however, not exactly parallel to the flotation recoveries obtained by these mixtures. It is evident, therefore, that the solid itself also affects the mineralized froth.

Cu powder, well-floating at pH 5.5 to 9.0, with dodecyl sulphate alone still gives a very good flotation if an equivalent amount of C.T.A.B. is added to the cell, though the resultant froth is much more stable and too voluminous for commercial purposes. However, if an equivalent amount of dodecyl amine hydrochloride is added to the solution of dodecyl sulphate floating Cu, the flotation is completely suppressed. This was found to be due not only to the suppression of frothing itself, but also to the actual desorption of dodecyl sulphate from Cu surface by the complexing action of amine. Residual Cu powder is completely hydrophilic and free to adsorb another collector, like xanthate or even excess of dodecyl sulphate, if added above the equivalent amount of amine hydrochloride. Presence of strong alkyl sulphate—alkyl amine complex in the solution is, however, hindering to efficient adsorption and froth formation of excess dodecyl sulphate (and xanthate plus frother) and prolonged conditioning seems to be required to overcome the interference of the complex in solution. If the harmful complex is decanted, the residual Cu powder reacts with further added collector and frother at a much higher rate and flotation takes place almost immediately.

The concept of molecular interactions between collector and frother molecules makes it possible to visualize the process or mechanism involved in dynamic attachment of air bubbles to solid particles. Fig. 8a shows the distribution of collector and frother molecules at interfaces and in bulk solution at optimal flotation conditions, as an air bubble and a particle approach each other. Both at the air/water interface and at the solid/water interface *diffuse monolayers* of associated and unassociated collector and frother molecules are present, temporarily in equilibrium with molecules in bulk solution. The film at the solid surface differentiates from that at the air/water interface insofar as the collector molecules are irreversibly adsorbed (under given flotation conditions) and the frother molecules are free to adsorb and desorb. As soon as the air bubble contacts the solid surface, Fig. 8b, the collector-frother molecules of the air/water interface can now penetrate the diffuse monolayer at the solid, and adsorb strongly onto the solid surface, greatly increasing *local* surface concentration and *local hydrophobic* character of the surface. At the moment of attachment of a particle to an air bubble the mixed monolayer at the air/water interface becomes slightly more condensed and consequently the bubble is stabilized. A well-mineralized bubble constitutes a more stable froth system.

If the films at the air/water and the solid/water interfaces, Fig. 8a, are too highly condensed, the adherence of the bubble is temporarily prevented, since a stabilized hydrophilic surface of the air bubble is approaching a stabilized hydrophobic surface of the solid, giving initial conditions for the formation of a bimolecular-leaflet micelle, the so-called armoring of bubbles. These conditions are achieved more readily by strongly associating collector and frother molecules, although the concentration of collector may be still far from the critical

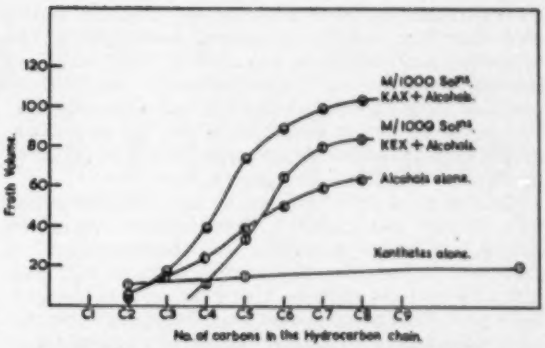

Fig. 7—Effect of xanthate addition on frothability of straight-chain alcohols. Molecular associations between collector and frother, in relation to froth volume.

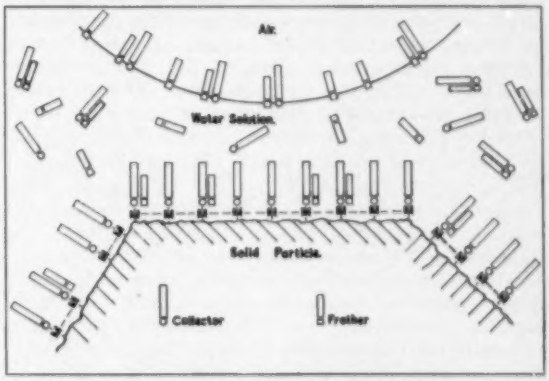

Fig. 8a—Mechanism of bubble attachment: bubble approaching a collector-coated solid surface; diffused monolayers of associated and unassociated molecules at interfaces and in solution.

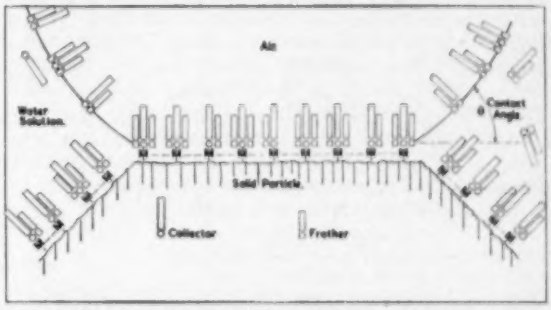

Fig. 8b—Mechanism of bubble attachment: adherence of an air bubble established through the penetration of the monolayer at the solid/liquid interface by the monolayer at the air/liquid interface.

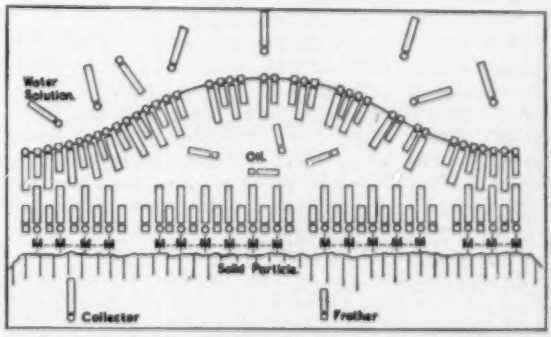

Fig. 9—Mechanism of oil-spreading on a highly hydrophobic solid surface.

concentration for micelle formation. It can be readily seen that with a fully condensed monolayer of the collector immobilized on the solid surface, no penetration by the frother molecules can be obtained, in contrast to the case with frother/collector penetration at the air/water interface, where the monolayer molecules are mobile. The impossibility of penetration prevents bubble attachment.

Gaudin et al.,[13a, b, c] Simard et al.,[19] and Schulman and Smith[20] have shown that without exception optimum flotation recoveries are obtainable with a fraction of a collector monolayer coverage, e.g., with diffusely covered surfaces. Using radioactive isotopes, Beischer[21] has demonstrated experimentally that the molecules adsorb primarily on corners and edges of scratches, where the surface energy is minimum and the adsorption energy maximum.

The strongly hydrophobic nature of densely collector-covered surfaces which prevents penetration by frother molecules causes further (a) adherence of particles to one another (flocculation, due to van der Waals forces) and (b) spreading of oils (derived from flotation reagents and from mining operations) and of the degradation products, such as dixanthogens. In the case of oil-spreading flotation is impaired owing to engulfment of bubbles by the oil films (overoiling phenomenon), which decreases the firmness of bubble adherence. The spread oil films also dissolve the frother molecules and remove them from the flotation pulp. Fine particles, possessing many highly reactive edges and corners, are more susceptible to overoiling and this is an additional cause for their non-floatability, besides the aging of surfaces, as described by Gaudin et al.[22]

Fig. 9 shows how contact angles greater than 90° can be easily obtained by replacement of air by oil. The much more readily stabilized monolayer at the oil/water interface can form a bimolecular leaflet with the collector-frother coated surface, giving higher angles which are impossible to attain at the air-water. This is readily explained by the fact that the surface tensions at the air/water ($\gamma a/w$) interface are rarely lowered by surface active agents to less than 30 dynes per cm, whereas the surface tensions of less than 1 dyne per cm can be easily obtained at the oil/water interface, $\gamma o/w$.

The following relationship holds:

$$\frac{\gamma s/o - \gamma s/w}{\gamma o/w} = \text{Cos}\,\theta$$

Waterhouse and Schulman[23] have shown by electron-diffraction pattern that the diffusely collector-covered solid surface is penetrated by frother molecules, giving a new diffraction pattern of the mixed monolayer.

Summary

The experiments carried out with a variety of pure surface active agents, employed in flotation of ores as either collectors or frothers, show that (a) long-chain homologues of alcohols and alkyl sulphates react strongly with xanthates at the air/liquid interface (Langmuir-trough experiments); (b) the reactions between frothers and collectors occur at the solid/liquid interface, if the solid is suitably coated by collector molecules (frother abstraction tests); and (c) the effects of molecular associations collector-frother are evident in frothing and flotation results. The measurements of air/water/solid and oil/water/solid contact angles (carried out under variable conditions as regards concentration of the surface active agents, pH, time of conditioning, and presence of complexing agents in the oil phase) reveal the importance of the density of collector-coverage. A mechanism for attachment of suitably collector-coated particles to an air bubble is postulated.

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The Time Is Now — Annual Meeting 1954 — New York City

LEADING off with the Welcoming Luncheon at the Hotel Statler, the Annual Meeting in New York, February 15 to 18, will present one of the most attractive lists of social functions in its history.

Prime attraction of the Welcoming Luncheon Monday will be Dr. Grayson Kirk, president of Columbia University. Dr. Kirk will speak on the Bicentennial Celebration of Columbia. Special tables have been reserved for wives of men at the head table, and for student paper award winners. Price for the Welcoming Luncheon is $4.50. James Boyd is Chairman of the Welcoming Luncheon committee. Members of the committee assisting him are: Mrs. Francis Cameron, Mrs. Lyman Hart, Darwin Pope, W. J. Turner, Julian W. Feiss, and Park Hodges.

The Penn Top and Sky Top rooms of the Statler will be open from 6:00 pm to 7:30 pm Monday for the pre-smoker cocktail party, free to all registrants. Annually, the cocktail party, sponsored by several companies, has served to help renew old friendships and strike up new ones.

With the Latin Quarter show as the feature attraction, the Dinner-Smoker will begin at 8:00 pm Monday. The Latin Quarter is one of New York's most famous night clubs and its shows are always spectacular. The current edition is said to be one of the greatest in the club's history. The costuming is unusual, the talent resplendent, and the acts better than ever. Price for the Latin Quarter show and the Dinner-Smoker has been pegged at $10.00. C. DeWitt Smith is Chairman of the committee, while Louis C. Raymond serves as Vice-Chairman. Committee members are Frederick R. McIntosh, Joseph B. Terbell, and Austin Goodyear. The Michigan School of Mines will hold a cocktail party and dinner in the Penn Top North Statler Hotel, at 6:00 pm on Tuesday.

One of the most attractive events Tuesday evening will be the Informal Dance, scheduled to start at 9:00 pm. Refreshments wil be available throughout the evening. An audience participation program has been planned and door prizes will go to lucky ticket holders. Tickets for the dance are $3.50 each. C. P. Jenney is Chairman of the committee, with Mrs. Robert Rowan and David T. Steele assisting him.

The Montana School of Mines Alumni group will meet for cocktails at 6:30 pm on Tuesday, and dinner will be at 7:30 pm in Parlor A at the Statler. Ladies are invited.

Another collegiate event on Tuesday will be the Missouri School of Mines Alumni Association Annual Dinner, with cocktails at 6:15 pm and dinner at 7 pm. Scheduled for the Building Trade Employers Assn., at 2 Park Avenue, tickets are priced at $5.50 per person. For reservations call James L. Head, Room 1726, 25 Broadway, New York City. A third alumni group who will get together are the graduates of Michigan College of Mining and Technology. Cocktails precede dinner and the affair is scheduled for the Penn Top North at the Hotel Statler at 6 pm, Tuesday.

Tickets for the Scotch Breakfast, slated for Tuesday morning are $5.00. The breakfast, a tradition of the Minerals Beneficiation Div., will include entertainment and will be held in the Cafe Rouge of the Statler.

Jackling Award

Fred Searls, Jr., chairman of the board of Newmont Mining Co., will present the Jackling Award to Reno H. Sales during the Mining, Geology, and Geophysics Luncheon, 12:00 Noon, Tuesday.

The Annual Banquet is at 7:00 pm, Wednesday, in the Waldorf-Astoria Ballroom. Presentation of awards and honors will follow dinner and it is guaranteed that there will be no long speeches. All those attending will receive favors. The President's Reception will be held in the East Foyer following award presentations. Dancing will be from 10:00 pm to 2:00 am. Tickets for the Banquet are $12.00 each. While dress is optional, black tie is preferred. Members of the Banquet Committee are: J. T. Sherman, Chairman; John Payne, Jr., Vice-Chairman; Kenneth E. Hill; Henry W. Hitzrot; W. A. Mudge; Robert B. Fulton; Frank R. Milliken; Mrs. E. H. Robie, and Mrs. H. DeWitt Smith.

Registration for ladies who are members of WAAIME will be $1.00, and for nonmembers $2.00. The New York Section of the WAAIME will be hosts at a welcoming coffee party immediately after Monday morning registration. Monday's round of social functions will of course include the Welcoming Luncheon and evening cocktail party. The WAAIME will hold its Annual Meeting Tuesday morning. A Luncheon and Fashion Show follows on the Starlight Roof of the Waldorf Astoria, with each lady receiving a favor. Tickets are $6.00 each. The Informal Dance, Banquet, and round table discussion round out the week's activities.

Evan Just has been performing the various and many tasks of the Annual Meeting Reception Committee. Assisting him have been Alvin W. Knoerr, Rene J. Mechin, J. F. Myers, John F. Ffolliott, James Wroth, and Clement Pollock. Robert Ramsey is Chairman of the General Committee. Alvin W. Knoerr is Secretary. Vice-Chairmen of the group are G. Howard LeFevre, and John Ffolliott, while James S. Vanick is Treasurer.

The following winners of the 1953 National Student Prize Paper Contest have been announced, and they have been invited to be guests of the Institute at the Welcoming Luncheon at the Annual Meeting. All are undergraduates, no graduate papers of sufficiently high standard having been entered this year:

Russell M. Corn, Student Associate at Montana School of Mines, for his paper *Fluorite Deposits in the Dry Creek District near Superior, Mineral County, Montana*, entered by the Montana Section.

James Milo Stewart, Student Associate at the University of Kansas, for his paper, *Calculation of Gas Reserves in a Small Kansas Gas Pool*, entered by the Kansas Section.

James Lommel, Student Associate at the Illinois Institute of Technology, for his paper, *Isothermal Grain Growth in OFHC Copper*, entered by the Chicago Section.

LEO F. REINARTZ

President, AIME, 1954

TALK to Leo F. Reinartz, the people who know him, and the men who work under him, and one transcending factor emerges—his devotion throughout his industrial career to a philosophy of teamwork and cooperation.

It has been the idea he has carried during his 44 years with Armco Steel Corp.—from chemist to vice-president in charge of mines, quarries, and special operating development. His philosophy has spilled generously over into community life. Mr. Reinartz plans to bring that feeling for teamwork and cooperation to the AIME Presidency.

Couple this attitude with a quiet confidence and Leo Reinartz begins to take form as a concrete individual with reverence for the inquisitive mind and faith in the future of the steel industry.

The day in 1909 when he came to Armco Steel was a big one for Leo Reinartz. He was a young man fresh from Carnegie Institute of Technology. The years behind him had been important ones—filled with experience and learning. The years ahead would see him become open hearth foreman, superintendent of open hearths, assistant general superintendent, manager of the Middletown Div., and assistant vice-president. He held the position of manager for 21 years.

Mr. Reinartz came from a large family. With five brothers and one sister, even the $35 per year tuition at Carnegie Tech presented problems. An odd assortment of jobs furnished the money for room, board, and books. In his freshman year Mr. Reinartz worked as conductor on a Pittsburgh streetcar. Later, he was employed as a laboratory assistant

and he also taught chemistry to nuns. Summers he worked on a farm for a dollar a day. If it rained, Mr. Reinartz recalled, he wasn't paid.

When Mr. Reinartz was a student at Carnegie Tech, practical applications were emphasized. Not enough time was devoted to theory, according to Mr. Reinartz. He feels that metallurgical engineering curriculum today is better adjusted to the needs of the student. However, Mr. Reinartz makes two reservations. He says, "There is a definite need for more instruction in personal and public relations. Young engineers should be taught that every business has a personality—good, bad, or indifferent. They must learn that they have an important part to play in the shaping of that personality. There is also a need for greater emphasis on the Humanities. The engineer must be a whole man—not just a technician or scientist."

Foundation for his views stems from his years as a student in Pittsburgh and his earlier years in East Liverpool, Ohio, where he was born. Mr. Reinartz feels that bad management and lack of understanding were responsible for many of the strikes that ripped Pittsburgh during the first part of the 20th century. Conversely, his Lutheran minister father had been the arbitrator in a number of strikes in East Liverpool. Mr. Reinartz early learned the efficaciousness of common sense in labor disputes. And there were other, more personal battles fought in East Liverpool. Contracting polio at the age of three, Mr. Reinartz struggled to regain the use of weakened muscles. With his mother as an inspirational force, he endeavored to make his mind do the work his muscles could not, and at the same time he started using the gym at the YMCA under special dispensation. A measure of his success is indicated by the fact that he made his high school track team as a high jumper and competed later on in Armco industrial track meets.

It was across the river from East Liverpool at Chester, Va., that the desire to become part of the metals industry was born. Invited with his father to inspect a tin plate mill, Mr. Reinartz saw red hot sheets of metal, felt the heat, and heard the noise and decided they added up to the most glamorous thing in the world. He says, "I decided that it was the kind of work I wanted to do and I never changed my mind." Today, ask Leo Reinartz if he has a hobby and he answers, "My vocation, avocation, and continuing interest is the making of better steel."

In keeping with this absorption with his life's work, Mr. Reinartz has been one of the driving forces behind the National Open Hearth Conference of the AIME since attending its first meeting in 1925. Serving as its Chairman for 18 years, he strove mightily to make it a successful dynamic organization. He believes that the interchange of steelmaking knowledge promoted by the National Open Hearth Conference did much to make possible the tremendous increase in steel production from already existing facilities during World War II. Mr. Reinartz is now a Life Member of the National Open Hearth Conference.

All of Mr. Reinartz's 44 years with Armco have been at the Middletown works. He went there because a college professor had told him it was a company with a future. He knew little more about the corporation. A lot of Middletown residents knew even less. During his first years with Armco he set about learning all he could about open hearths. In addition to many technical improvements he has been responsible for certain other things—perhaps less tangible but of great importance. He helped convince the plant's operating and labor force that good housekeeping and good steel production go together. Mr. Reinartz started a campaign to enliven the inside and outside of the plant by use of bright colors and the planting of trees, flowers, and grass around the grounds.

Also as manager he began a newsletter to employees, telling them what was going on in the company. Today, the various works managers continue the practice. He sees Institute headquarters serving somewhat the same function of information distribution.

"Headquarters should serve as a clearing house for local sections, with its primary function the supplying of information and the giving of aid to local groups. It is the place where local sections are helped to help themselves. Institute control should be decentralized, with no group or individual exercising more than a fair share of authority."

Mr. Reinartz also feels that the office of the presidency cannot be successfully carried out by one man. The phenomenal growth of the AIME makes its imperative that the Institute's chief executive get help.

"I plan to form a voluntary group to assist in spreading the Institute gospel to colleges and local sections. Right now, AIME interest among certain faculty members and student bodies is not as intense as it could be. If the AIME story is presented properly I am sure we can look forward to the growth of strong campus student chapters."

Mr. Reinartz is a member of a long list of technical and civic groups. Among them are: American Management Assn.; Iron & Steel Engineers Assn.; National Chamber of Commerce; Board of Directors of the Hospital Care Assn., South West Ohio; Minerals and Metals Advisory Board, National Academy of Sciences; Vice President, Middletown Savings & Loan Assn.; Treasurer, Middletown Industrial Council; Board of Directors, Middletown Safety Council; Chairman, Red Cross Blood Procurement Committee, Middletown; and Board of Regents, Capital University, Columbus, Ohio.

Mr. Reinartz maintains an interest in developments in steelmaking abroad as well as in the U. S. One plan for his term as AIME President is a trip to Europe to cement already good relations with engineers in England and on the Continent.

A chat with Leo Reinartz leaves the impression that here is a man whose eyes are on the future. He has no use for the prophets of doom and feels that "the next 50 years will bring marvels to the steel industry that will literally dwarf those of the last 50."

One day in 1916 stands out in Mr. Reinartz's mind. On that day he had a new promotion, a new wife, and a new home. He married Mathilda Zix and was also named open hearth superintendent. Mr. and Mrs. Reinartz had two daughters and a son. The son, Leo Reinartz, Jr., was killed while leading a tank charge on Leyte in 1944. He is survived by a daughter born three months before her father's death. Mr. Reinartz has one interest aside from profession and community—his five grandchildren.

Mr. Reinartz served as Vice-President of the AIME from 1945 to 1948 and has been a Member of the Board of Directors. He is a Past Chairman of the Iron and Steel Div., Past Chairman of the Membership Committee, and served for many years on the Physical Chemistry of Steelmaking Committee.

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1954 SOCIAL FUNCTIONS ANNUAL MEETING

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SUNDAY, FEB. 14

5:30 to 7:30 P.M.
Mineral Industry Education Div.
Reception and Buffet Supper

MONDAY, FEB. 15

12:00 Noon
Welcoming Luncheon
Dr. Grayson Kirk,
president, Columbia University
6:00 P.M.
Cocktail Party (New York mining companies, hosts)
8:00 P.M.
Dinner-Smoker, Stag Dinner

TUESDAY, FEB. 16

8:00 A.M.
Minerals Beneficiation Div.
"Scotch Breakfast"
12:00 Noon
Mining, Geology, and Geophysics Div.
Luncheon
Coal Div. Luncheon
Institute of Metals Luncheon

Branch Cocktail Parties and Branch Dinners

Mining Branch	
Cocktail Party	6:00 P.M.
Dinner	7:00 P.M.
Speaker, Desmond F. Kidd	
Metals Branch	
Cocktail Party	6:00 P.M.
Dinner	7:00 P.M.
Petroleum Branch	
Cocktail Party	6:00 P.M.
Dinner	7:00 P.M.
Informal Dance	9:00 P.M. to 1 A.M.

WEDNESDAY, FEB. 17

12:00 Noon
Industrial Minerals Div. Luncheon
Extractive Metallurgy Div. Luncheon
7:00 P.M.
Annual Banquet and President's Reception

THURSDAY, FEB. 18

12:00 Noon
Minerals Beneficiation Div. Annual Luncheon

AIME Annual Meeting Program, Feb. 13 to 18, 1954

Hotels Statler and McAlpin, New York

Names of Divisions and Subdivisions are coded as follows: MIED—Mineral Industry Education Div. MED—Mineral Economics Div. M—Mining Subdiv. G—Geology Subdiv. Geophys.—Geophysics Subdiv. NM—(nonmetallics) Industrial Minerals Div. Coal—Coal Div. MBD—Minerals Beneficiation Div. EMD—Extractive Metallurgy Div. IMD—Institute of Metals Div. ISD—Iron & Steel Div. Petroleum Branch—Named as such. SEG—Society of Economic Geologists.

All Metals Branch sessions will be held in the Hotel McAlpin, and all Mining and Petroleum Branch sessions will be held at the Hotel Statler.

SATURDAY, FEBRUARY 13

10 am
Council of Section Delegates

SUNDAY, FEBRUARY 14

2 pm
Board of Directors

2:30 pm
IMD, MIED—Columbia Univ.

5 pm
IMD Program Committee

7:30 pm
IMD, MIED

MONDAY, FEBRUARY 15

8 am
Registration

9 am
Petroleum Branch—*Executive Committee*

9:45 am
EMD—*Aluminum*
EMD—*Arc Furnace Copper Melting*

9:45 am
ISD—*Surface Quality of Bars*

9:45 am
IMD—*Semi-Conductors*

10 am
NM—*Fluorspar*
M—*Drilling Problems*
NM—*Dimension Stone and Slate* (closed session)
MBD—*General Business Session*
Coal, CIMM—*Mining Methods in Relation to Recovery*
Metals Branch Council Meeting

12 noon
Welcoming Luncheon
Grayson Kirk, president, Columbia University

2 pm
Petroleum Branch—*Technical Session*
M—*Drilling Problems*
G—*Base Metal Deposits*

2:30 pm
G—SEG
NM—*Ceramics Raw Materials*
NM, MBD—*Cement, Lime, Gypsum*
MBD—*Materials Handling*
MBD, MIED
Coal—*Preparation, Coarse Coal*
EMD—*Aluminum*
EMD—*Arc Furnace Copper Melting*
ISD—*Open Hearth Combustion*
IMD—*Semi-Conductors*
IMD—*Deformation*

3 pm
Peele Award Committee
JOURNAL OF METALS Editorial Advisory Board

4 pm
MGGD Executive Committee

4:30 pm
IMD Membership Committee

6 pm
Cocktail Party

8 pm
Dinner-Smoker

TUESDAY, FEBRUARY 16

7:30 am
EMD Executive Committee Breakfast
IMD Titanium Committee Breakfast

8 am
MBD Scotch Breakfast

9 am
Petroleum Branch—*Technical Session*
M—*Block Caving*
M—*Stratified Mining*
G, SEG, NM—*Radioactive Materials*
NM—*Careers in Industrial Minerals*
NM, SEG, G—*Rare Minerals*
MBD—*Crushing and Grinding*
MBD—*Operating Control*
Coal, CIMM—*Preparation, Fine Coal*
Geophys
EMD—*Lead-Zinc*
EMD—*Hydrometallurgy—Physical Chemistry*
ISD—*Use of Rare Earths*
IMD—*Deformation*

10 am
Mining Branch Council

11 am
Howe Memorial Lecture
by C. D. King

12 noon
MGGD Luncheon
Coal Luncheon

12:15 pm
IMD Executive Committee Luncheon

2 pm
Petroleum Branch—*Economic, Geological, Political Factors of World Oil Production*
NM—*Rare Minerals*
MBD—*Concentration*
Coal—*Mining Methods*
EMD—*Lead-Zinc-Cadmium*
EMD, MBD—*Hydrometallurgy*—Statler
ISD—*Ingot Examination and New European Practices*
IMD—*Constitution*
IMD—*High Temperature Properties*

2:30 pm
MGGD
Jackling Lecture

6 pm
Metals Branch Cocktail Party
Petroleum Branch Cocktail Party and Dinner

7 pm
Metals Branch Annual Dinner

9 pm
Informal Dance, AIME

WEDNESDAY, FEBRUARY 17

7:30 am
ISD Executive Committee Breakfast

9 am
M—*Greater Butte Project*
G, Geophys
NM—*Special Sands and Abrasives*
MBD—*Concentration*
MBD—*Solids-Fluids Separation*
Coal—*Continuous Mining*
EMD, IMD—*Physical Chemistry of Extractive Metallurgy*
EMD—*Titanium*
ISD—*Physical Chemistry*
IMD—*Solidification*

9:30 am
Petroleum Branch—*Technical Session*

11 am
IMD Annual Lecture
by Bruce Chalmers

12 noon
NM Luncheon
MIED Luncheon

12:15 pm
EMD Stag Luncheon and Business Meeting

2 pm
M—*Underground Mining Problems*
G—*Porphyry Copper Deposits*
MED
NM
EMD—*Physical Chemistry of Extractive Metallurgy*
EMD—*Copper*
ISD—*Blast Furnace*
IMD—*Constitution*
IMD—*Titanium*

2:30 pm
Geophys, G
MBD—*Pyrolysis and Agglomeration*
Coal—*Air and Water Pollution*
Coal—*Strip Mining*

4:30 pm
NM Executive Committee

7 pm
Annual Banquet
President's Reception

THURSDAY, FEBRUARY 18

9 am
M—*Support of Mine Workings*
MGGD, NM—*Industrial Waters*
MBD—*What's New in Milling*
Coal—*Utilization*
EMD—*Uncommon Metals*
IMD—*Steel*
IMD—*Powder Metallurgy*

12 noon
MBD Luncheon

12:15 pm
IMD Powder Metallurgy General Luncheon

2 pm
MGGD, NM—*Industrial Waters*
MBD—*Clean-up Session*
Coal—*Utilization*
IMD—*Powder Metallurgy Seminar*

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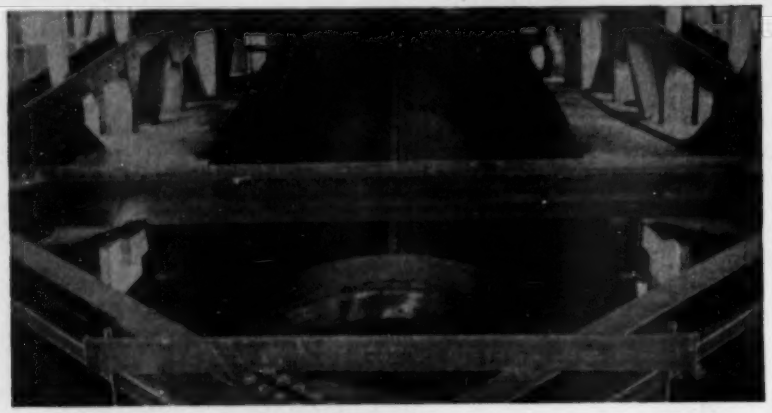

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Preliminary Budget For 1954 Adopted

A preliminary budget for 1954 was adopted by the Executive and Finance Committees of the AIME at their Dec. 16, 1953 meeting. It will be reviewed and a final budget adopted next spring. Income for 1954 is set at $697,000 and expenses $678,300, leaving an expected surplus of $18,700 for further replenishment of reserve funds which were virtually exhausted to meet the deficits of 1946-50. Income from dues is expected to be $366,500, or 53 pct of the total; advertising should net $233,000, or 33 pct; sales of publications, $72,500, or 10 pct; and initiation fees, $21,000, or 3 pct.

Publications

Major expense is for publications, $374,800, or 55 pct of the total. Service of one kind or another to Branches, Divisions, Local Sections, Student Chapters, and members totals $132,000, or 19 pct. This includes the expense of the Salt Lake office, a good share of the expense of the Dallas office except that charged to publications; membership promotion and processing, Local Section appropriations and Section Delegates' travel, salaries and expenses of Division and Branch secretaries, and library service. The remaining quarter of Institute income, $171,500, is expected to cover all expenses of the Secretary's office including his travel; expenses of the business office, including office management, purchasing, accounting, filing, shipping and receiving, Addressograph, Multilithing, orders, and all expense chargeable to the Directory; pensions and related expense; insurance, and depreciation.

Branchwise, income is expected to be $314,445 for Mining, $189,435 for Metals, and $193,120 for Petroleum. Expense is divided $290,960 for Mining, $206,272 for Metals, and $181,068 for Petroleum. Present division of the AIME membership is Mining, 48.5 pct, Petroleum 26 pct, and Metals 25.5. Compared with ten years ago this represents an increase of about 10 percentage points for the Petroleum Branch and a decrease of like amount for the Mining Branch.

In considering a rough draft of the budget prepared by the staff, the Committees decided to reduce expenses by $4500 through a reduction in the number of Institute of Metals Transactions pages from 750 to 650, and by postponing the next issue of the AIME Directory to early 1955. A supplement, similar to that issued last spring, containing the names of officers and committee personnel, will, however, again be issued in the spring of 1954. An important item in the cost of the complete Directory is now some $6000 for postage, as the volume must now be sent by third class mail instead of second class as a separate section of the journals.

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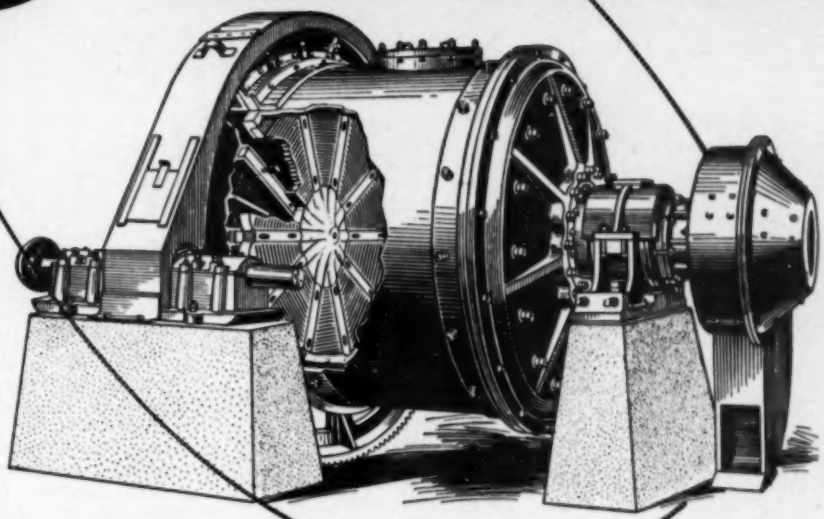

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REPRESENTATIVES IN FOREIGN COUNTRIES

Around the Sections

• The **St. Louis Section** adopted a resolution citing the "faithful and inspiring service" of Herbert R. Hanley to the group and to the AIME. Mr. Hanley has left for Formosa as a technical consultant to the U. S. State Department. The resolution reads:

Whereas:

He has served this section most faithfully as Chairman, speaker, and inspiration and

Whereas:

He is leaving temporarily to devote his energies in spreading the gospel of metallurgy in foreign lands Therefore Be It Resolved that

The St. Louis Section of the AIME sends with him its heartiest wishes of success and enjoyment in his new work and regrets that, even though only temporarily, it will be without his presence....

• The Ore Dressing Div. of the **Arizona Section** heard Harmon E. Keyes, Phoenix chemical and metallurgical engineer, discuss *Commercial Scale Plants Producing Acid or Ferric Sulphate by Autoxidation.* The meeting was held at the Pioneer Hotel, Tucson, with 49 students, guests, and members attending. Another paper of interest to those attending was *Leaching of Vanadium and Uranium Ores on the Colorado Plateau,* by E. J. Duggan, consultant, Climax Uranium Co. George Sewell, assistant concentrator supt., Kennecott Copper Corp., Hayden, Ariz., was elected 1954 Chairman of the Division.

• William H. Durrell, general manager, Hollinger-Hanna Ltd., spoke to the **Chicago Section** on *The Labrador-Quebec Iron Ore Development* at a meeting held at the Chicago Bar Assn. L. H. Timmins, president, Chromium Mining & Smelting Corp. Ltd., Montreal, acted as technical chairman. Clayton G. Ball was the presiding officer.

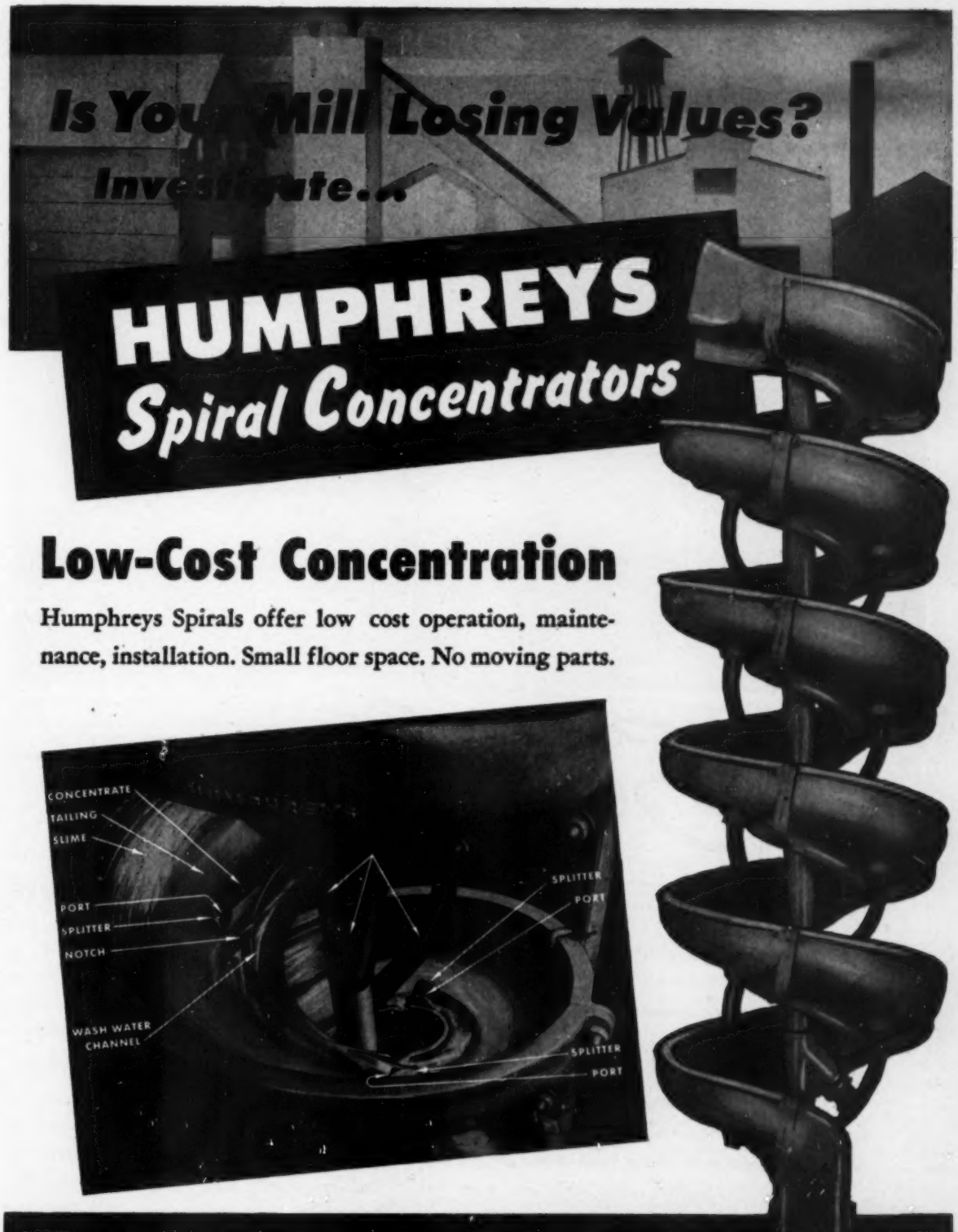
• Roger V. Pierce has been elected Chairman of the **Utah Section** for 1954. J. M. Ehrhorn has been named Vice Chairman. Other officers elected for the year are: Carleton R. Fish, Secretary-Treasurer; Warren Woodward, L. J. Westhaver, V. L. Stevens, and Clark Wilson, Executive Committee; D. F. McElhattan, Chairman of the Membership Committee; Burt B. Brewster, publicity; W. L. Lippert and Robert W. Lawson, Entertainment Co-Chairmen; and J. E. Cone, Student Affairs Chairman. The February meeting of the section will feature a panel discussion on the education of engineers. G. Homer Durham, vice president of the University of Utah, is scheduled to be moderator. The University of Utah debating teams, nationally acclaimed, will take part in the dinner-meeting scheduled for March 11. Subject of the debate will be *Tariff vs Free Trade.*

• As in the past, the December meeting of the **San Francisco Section** was taken over by the annual Christmas Jinx. Herb Sawin did an excellent job of arranging for the evening's entertainment. Following the program, several members played cards.

• Air Reduction Co. Inc. has just issued a new sound slide-film on safety in the use of oxyacetylene cutting and welding equipment. The film, *The Guy Behind Your Back,* is reportedly a fundamental approach to safety factors affecting welding, cutting torches, and cutting machines. It is designed to aid companies in training employees. Free showings may be arranged by getting in touch with the Air Reduction office in your area. Information may also be obtained by writing Air Reduction Sales Co., 60 East 42nd Street, New York 17, N. Y.

• A 16 mm color and sound movie is being distributed for free showings by D. W. Onan & Sons Inc., Advertising Dept., Minneapolis 14, and is called *Onan on Safari.* The film was made by Attilio Gatti on his recent expedition to Africa. Much of the film deals with the use of Onan equipment to supply electricity for everything from refrigerators to communications equipment, to lighting for cameras and camp.

• L. L. McDaniel was elected chairman of the Smelting Div. of the **Arizona Section** at a recent meeting at Tucson. J. B. Cunningham was elected Secretary. Four papers were heard at a session devoted to material handling. They were: *Mechanical Handling of Blister Copper at Hayden,* by H. G. Simmons, American Smelting & Refining Co.; *Material Handling and Mechanization at Morenci Smelter,* L. L. McDaniel, Phelps Dodge Corp.; *Material Handling and Mechanization at Douglas Smelter,* H. F. Lindsey, Phelps Dodge Corp.; and *Material Handling and Mechanization at Ajo Smelter,* by J. W. Byrkit, Phelps Dodge Co. The session was in conjunction with the Arizona Section Annual Meeting.



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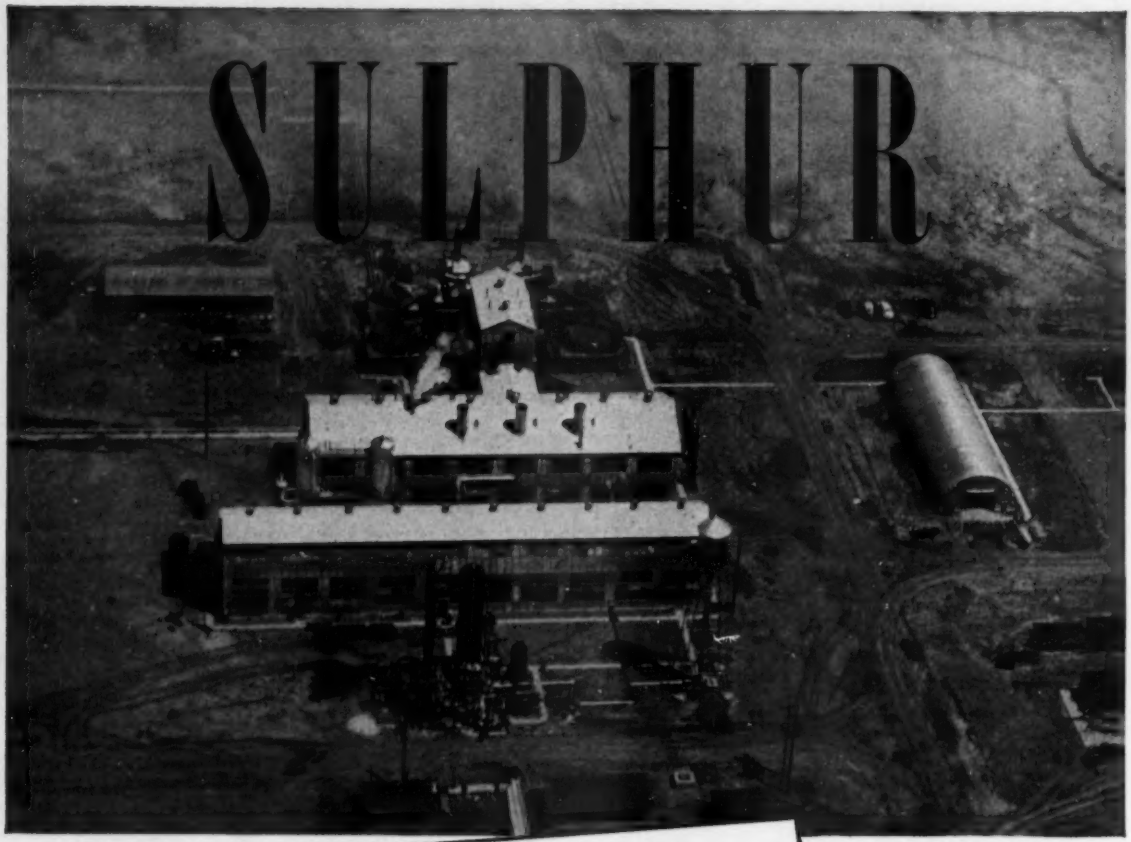

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Personals

PLATO MALOZEMOFF

PHILIP KRAFT

MARCUS D. BANGHART

Charles F. Ayer, chairman of the board of Newmont Mining Corp. since 1947 and prior to that president of the company since 1925, has retired and been named honorary chairman. **Fred Searls, Jr.,** president since 1947, is now chairman of the board and **Plato Malozemoff,** vice president, is president. **Franz Schneider** has retired as executive vice president, but will continue to serve Newmont as a consultant. **Philip Kraft** and **Marcus D. Banghart** are vice presidents. Mr. Kraft has been president of Newmont Oil Co., a wholly owned subsidiary, since its formation about 10 years ago. Mr. Banghart is managing director of O'okiep Copper Co. Ltd. and Tsumeb Corp. Ltd., African affiliates of Newmont.

Richard V. Wyman has resigned from the New Jersey Zinc Co. and is now chief geologist of Western Gold & Uranium Inc. at the Silver Reef uranium mines, Leeds, Utah.

Arthur C. Wilby has retired as vice president of United States Steel Corp. in Chicago and has been succeeded by **Edward C. Logelin.** Mr. Logelin joined U. S. Steel in 1930.

V. A. Gorsky, consulting mining engineer and metallurgist, has joined the geological dept., University of Natal in Durban, South Africa, doing research work and lecturing on engineering geology.

Elza Fain Burch is coal preparation engineer with Red Jacket Coal Co., Red Jacket, W. Va.

Paul T. Allsman, formerly director of Region V of the U. S. Bureau of Mines, Minneapolis, has been named director of Region VII, Knoxville, Tenn. Succeeding Mr. Allsman is **M. E. Volin,** chief, Mining Div., Region II of the USBM, Spokane, Wash.

Frederick R. McIntosh, manager of the ores and concentrates div., and **Alexander McKnight,** manager of the general commodities div., have been appointed assistant vice presidents of C. Tennant Sons & Co., New York. Mr. McKnight has been with Tennant for the past 28 years. Mr. McIntosh came to the company 8 years ago, after service as a mineral specialist with the Foreign Economic Administration, and later the RFC during World War II.

FRED SEARLS, JR.

Robert P. Koenig has been elected to the board of trustees of the Mutual Life Insurance Co., New York. Mr. Koenig, president and a director of Cerro de Pasco Corp., is also a member of the boards of the Empire Trust Co., Banco Wiese., Lima, Peru, Ayrshire Collieries Corp., and the Republic Coal & Coke Co.

Louis K. von Perbandt has retired as president of Mines Engineering Co. because of ill health, but will continue as a consultant for the company. The Mines Engineering Co. will be operated as a division of the Paul Weir Co. with **Paul Weir** as president.

Robert L. McChain is manager of coal mining machinery sales of the Cleveland Rock Drill Div., Le Roi Co. Mr. McChain, at present in Ebensburg, Pa., will be located in the Pittsburgh area in the near future.

George F. Coope, Jr., is recovery plant superintendent, Coronet Phosphate Co., Plant City, Fla.

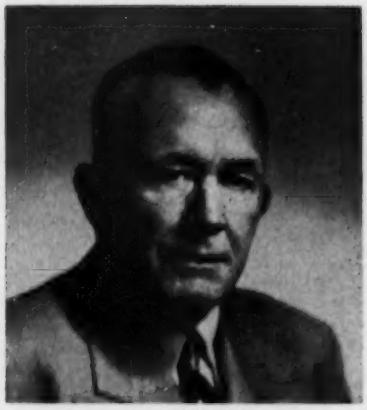
William R. Ellis, vice president and member of the board of directors of Hercules Powder Co., has retired after 39 years of service. As general manager of the explosives department during World War II, he directed the operation of six Government-owned plants as well as the company's own explosives operations. All the bazooka and other rocket propellant powders used by the U. S. armed forces were manufactured under his guidance.

George T. Harley, manager of the New Mexico properties of the potash div. of International Minerals & Chemical Corp. since 1944, became consultant for the potash div. in January 1954. Succeeding him as manager is **Carl A. Arend,** who has been assistant manager since July 1951. The potash div.'s mine and refinery are located at Carlsbad, New Mex., and Mr. Harley will retain his offices at the plant.

John M. Martin, general manager of Hercules Powder Co.'s explosive dept., and **John R. L. Johnson, Jr.,** director of the legal dept., have been elected directors of Hercules.

Pedro Horna Moreno is in charge of Chojilla mine, c/o International Mining Co., La Paz, Bolivia.

Myles A. Walsh, formerly in French Equatorial Africa, is now in Formosa where he is senior engineer for coal mining for J. G. White Engineering Corp.



C. J. ABRAMS

C. J. Abrams, general manager of western operations for the Climax Molybdenum Co., Denver, has been made head of a newly created exploration division. Succeeding Mr. Abrams is **Frank Coolbaugh,** resident manager of the Climax, Colo., operations.

Kenneth H. Klipstein has been appointed general manager of the newly created research division of American Cyanamid Co. This division will be responsible for the operation of the Stamford Research Laboratories under the direction of **J. T. Thurston.**

William H. Newton, formerly manager, Ore Beneficiation Div., Jeffrey Mfg. Co., Columbus, Ohio, is now with Western Machinery Co., San Francisco.

John V. N. Dorr, chairman, and **J. Delano Hitch, Jr.,** president of the Dorr Co., Stamford, Conn., have announced the promotion to vice presidential level of five senior department heads. These new officers are: **Frank H. Conover,** manager of the procurement & production dept.; **Harold B. Coulter,** head of the mechanical engineering dept.; **John D. Grothe,** manager of the consulting engineering dept.; **Douglas C. Reybold,** controller and director; and **Elliott J. Roberts,** technical director in charge of research development and the Westport mill.

Frederick D. Wright, research mining engineer, U. S. Bureau of Mines, has left on a 6 month's leave of absence for Durango, Mexico, where he will have charge of the operations at the San Martin mine near Sombrerete. His address is Cia. Minera San Martin, Durango, Dgo., Mexico.

Jay C. Shoemaker is mill superintendent, Black Rock Mining Co., Bishop, Calif.

Elmer E. Thiele is employed by Central Commercial Co., Northfield, Ill., as a mining engineer.

John P. Hamm, sales engineer for the Salt Lake territory, Wemco Div., Western Machinery Co., has been named San Francisco sales manager of the division.

James A. Redding is sales engineer for Barrett Haentjens Co. and Wilmot-Engineering Co., Hazelton, Pa.

Lyle F. Campbell has formed the Lance Exploration Engineering Co., 208 Vorbeck Bldg., Grand Junction, Colo., to explore for uranium ores on the Colorado Plateau. Mr. Campbell was with M. A. Hanna Co., Cooley, Minn.

J. PARNELL CAULFIELD

J. Parnell Caulfield, general manager, Western Mining Div., Kennecott Copper Corp., has been elected president of the Utah Mining Assn. for 1954. Serving as 1st vice president is **Otto Herres,** vice president, Combined Metals Reduction Co., and 2nd vice president is **L. F. Pett,** general manager, Utah Copper Div., Kennecott Copper Corp. **A. G. Mackensie** is vice president and consultant, **Miles P. Romney** is secretary-manager, and **Walter M. Horne** is assistant secretary-manager.

R. W. Lawson, general manager of the Consolidated Feldspar Dept., of International Minerals & Chemical Corp., Chicago, has been appointed administrative assistant to **Norman J. Dunbeck,** vice president Industrial Minerals Div. **E. W. Koenig** succeeds Mr. Lawson as general manager and **W. Branch Lawson** is assistant manager. **Charles E. Hunter,** geologist is now production manager of the Feldspar Dept.

Karl W. Jasper, president of Grandview Mines Inc., Spokane, Wash., was named president of the Northwest Mining Assn. at the 59th annual convention in Spokane in December. He succeeds **Frank N. Marr,** president, Spokane-Idaho Mining Co. Named as vice presidents were **Robert E. Sorenson,** vice president, chief engineer, and geologist, Hecla Mining Co., and **P. Evan Oscarson,** Spokane consulting engineer.

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Anders G. Kindahl is now technical advisor, Copco Pacific Ltd., San Carlos, Calif. His position as head of company operations at Spokane, Wash., is held by **Carlos E. Milner, Jr.** Succeeding Mr. Milner as manager of the Phoenix, Ariz., district office is **Howard L. Brown.**

Charles Will Wright was in Colorado in November examining uranium deposits on the Colorado Plateau. He returned to Washington in December to attend the Mid-Century Conference on "Resources for the Future" as a delegate of the Mining and Metallurgical Society of America.

H. R. HANLEY

H. R. Hanley, Professor Emeritus of metallurgical engineering at the University of Missouri, is in Formosa to organize a department of nonferrous metallurgy in the University of Taiwan, Tainan. He expects to be there from 1 to 2 years.

Howard L. Hartman, who received his Ph.D. degree in mining engineering from the University of Minnesota, December 17, plans to continue in a teaching capacity at the university for the present.

Mack C. Lake has retired as president of Orinoco Mining Co., a U. S. Steel Corp. subsidiary, but continues in a consulting capacity. Mr. Lake joined U. S. Steel in 1945 and directed exploration which led to the discovery in 1947 of the iron ore deposits in Cerro Bolivar, Venezuela. He became president of Orinoco in 1949 when the subsidiary was formed. He is succeeded by **Francis Thomas,** vice president.

Daniel A. Jones, assayer-engineer, Dept. of Mines, Nome, Alaska, has resigned. He will be replaced by **Peter Sandvik,** former assayer at Anchorage, in April when he is released from the Army.

R. R. Williams, Jr. is assistant manager of Colorado Fuel & Iron mining dept. Mr. Williams has been superintendent of blast furnaces at the Pueblo plant of CF&I for the past 6 years.

Charles Vignos, II, has been elected president of American Mine Door Co., to succeed his father, the late **Charles A. Vignos.**

William Price Craven, mining engineer, is with Howe Sound Mining Co., Chelan Div., Holden, Wash.

C. C. Sterns, consulting mining engineer, Grand Junction, Colo., has been ill with polio since September of last year. However, in the last 4 months, he has made such remarkable progress that he is again able to work. Mr. Sterns graduated from Michigan College of Mining and Technology in 1933. He was for several years superintendent for U. S. Vanadium Corp., Rifle, Colo.

G. F. Joklik, on leave of absence from the Bureau of Mineral Resources, Canberra, Australia, is studying geology at the University of Columbia on a Fullbright scholarship. Mr. Joklik is planning to organize a group of young men for a tour in late March by automobile of U. S. ore deposits.

Truman H. Kuhn, professor of geology and dean of the Graduate School, Colorado School of Mines, recently returned from Turkey where he estimated chromium reserves for a Turkish mining company. Mr. Kuhn spent nearly a month at the company's mining camp near the small town of Ohaneli, 120 miles south of Istanbul

BERNARD YORK

Bernard York, after 13 years as a member of the mining engineering faculty of the University of California, has resigned his position there and is now engaged in consulting and private mine operation. Mr. York's address is P. O. Box 163, Mina, Nev.

Harold V. Trask, mining and metallurgical engineer, formerly with Oglebay, Norton & Co., is now with Cleveland-Cliffs Iron Co., Cleveland.

Thomas Walker, Jr., who was with Hercules Powder Co., Duluth, is with Palmer-Bee Co., Hamtramck, Mich.

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Obituaries

Edson S. Bastin (Member 1913) died of coronary thrombosis Oct. 9, 1953. He was Professor Emeritus of economic geology, University of Chicago. Born in Chicago in 1878, Mr. Bastin received his A.B. in 1902 from the University of Michigan, his M.S. in 1903, and his Ph. D. in 1909 from the University of Chicago. During the Spanish-American War he served as a private with the Michigan 31st Voluntary Infantry. He gained his early experience with the U. S. Geological Survey in Maine and in western mining districts, following which he went to Chile to examine copper properties. In 1917 he was appointed chief of the Div. of Natural Resources, USGS, resigning in 1919 to become professor of economic geology at the University of Chicago. Mr. Bastin was the author of numerous geological reports and articles. He was at one time president of the Society of Economic Geologists and vice president of the American Assn. for Advancement of Science. In recent years Mr. Bastin had made his home in Ithaca, N. Y.

H. Cayford Burrell (Member 1935) died Nov. 9, 1953. He was the manager of raw materials development, Columbia-Geneva Steel Div., U. S. Steel Co., San Francisco. Born in Boston in 1903, Mr. Burrell received his B.S. and M.A. from Harvard. Before returning to the University to do graduate work, he spent three years with Cerro de Pasco Corp. in Peru as a geologist. The author and co-author of technical articles, Mr. Burrell was also geologist for Zinc Corp. Ltd., Broken Hill, N.S.W., Australia, and Oliver Mining Co. in Venezuela.

Bradford C. Colcord (Member 1948) died Aug. 16, 1953 in a Boston hospital where he had been receiving treatment since last April. Mr. Colcord was president of Woodward Iron Co., Woodward, Ala., until his resignation early in 1953. He was a board member of the National Assn. of Manufacturers and widely known in the mining and steel industry. He was born in Elk County, Pa., in 1897 and graduated from the University of Michigan in 1922 with a B.S. in mining engineering. He then worked for Jones & Laughlin Steel Corp., Pittsburgh, later transferring to Pittsburgh Crucible Steel Co., Midland, Pa., where he became superintendent of blast furnaces. He joined Woodward Iron Co. in 1935.

Robert J. Grant (Member 1899) died Nov. 24, 1953. He was a retired mining engineer, living in Pasadena, Calif. Mr. Grant was born in 1862 in Nova Scotia. He learned assaying in Arizona and then worked as an assistant superintendent at several small mines in Arizona and Colorado. In 1904 he became manager of the Cosmopolitan mine, West Australia, and later worked in Mexico. Mr. Grant was the author of articles that appeared in *E&MJ* and in *Mining and Science Press*. He was for a number of years with the Director of the Mint, Washington, D. C., and with the National Chinese Government Mint in Shanghai. Mr. Grant was a Legion of Honor Member of AIME. T. A. Rickard and A. Chester Beatty were two of the men who signed his application for Institute membership in 1899.

Frederick E. Hall (Member 1945) died Oct. 18, 1953 at a railroad station in Montreal while waiting to board a train for his home in Port Credit, Ont. Mr. Hall was vice president and general manager of Ascot Metals Corp. Ltd., Sherbrooke, P. Q., and also vice president and general manager of Eastern Metals Corp. Ltd., and Quebec Nickel Corp. He was born in Menlo, Kans., in 1909, and went to Canada at an early age. After studying at Western Canada College, he worked for four years as a cyanide and flotation mill operator, construction foreman, and for a year operated his own transportation business. He joined Macassa Mines Ltd., Kirkland Lake, Ont., as a mill operator in 1933. Among other companies Mr. Hall later worked for were Pickle Crow Gold Mines Ltd., Gold Eagle Gold Mines Ltd. and West Marlartic Mines Ltd. He was a member of the Canadian Institute of Mining and Metallurgy.

Eero Mäkinen (Member 1948) died Oct. 27, 1953. He was managing director of Outokumpu Oy, Helsinki, Finland, and had been with the company since 1921. Mr. Mäkinen was born in Sortavala, Finland, in 1886 and earned his Ph.D. at the University of Helsinki, his E.M. at the Technical University of Stockholm. A geologist with the Geological Survey of Finland, he lectured for several years on mineralogy at the University and Technical University in Helsinki. Mr. Mäkinen wrote numerous technical articles and bulletins, as well as *Common Minerals and Metals*, a popular account in Finnish for the general reader.

T. S. McDougal (Member 1940) died Mar. 28, 1953. He was a mine operator and manager. Mr. McDougal was born in DeKalb, Miss., in 1866 and went to Jacinto Academy. On his AIME application he wrote that he had "no technical education," but had acquired his knowledge from "45 years of work at all positions from mucker to superintendent." He first went to work for Old Dominion Mining Co., Globe, Ariz., and after various jobs as mine foreman went to Ontario where he became assistant superintendent to F. A. Heinzer at West Dome, Porcupine. He was at the Fern mine, Wasilla, Alaska, for many years. He began as mine foreman, became superintendent, and later operated this property under lease. In recent years Mr. McDougal lived in La Veta, Colo., where he had formerly operated a coal mine.

John L. McNulty (Member 1946) died Aug. 22, 1953 of a heart attack. He was chief metallurgist and chemist, Anaconda Copper Co., Grants, N. Mex. He had also worked for Anaconda as a chemist in Georgetown, British Guiana. He was born in Kingman, Ariz., in 1912 and studied at St. Michael's College and the University of Southern California. After leasing and operating the Pioneer gold mine, Oatman, Ariz., for a short while, Mr. McNulty worked as an assayer, junior engineer, and then as a chemist for U.S. Smelting Refining & Mining Co.

Boyd C. Osler (Member 1918) died March 1952. He was a Hazelton, Pa., coal mining engineer. He was born in Shamokin, Pa., in 1881 and after graduating from high school in 1899, joined the engineer corps, Mineral Railroad & Mining Co. in Shamokin. Mr. Osler was at various times chief engineer for Maryd Coal Co., J. S. Wentz Co., Midvalley Coal Co.; general manager for Pardee Bros. & Co. Inc., Lattimer mines; and superintendent for the Monitor Co. Inc.

Russell J. Wilford (Member 1948) died Aug. 6, 1953. He was a director of Wilmot Engineering Co. and owner of the R. J. Wilford Real Estate and Insurance Agency, Hazelton, Pa. Mr. Wilford was born in Tamaqua, Pa., and graduated with a B.S. from the University of Pennsylvania in 1921.

Appreciation of

L. E. Young

by M. D. Cooper

Lewis Emanuel Young was born in Topeka, Kan., on Oct. 1, 1878, and died in Pittsburgh, Pa., on Dec. 27, 1953.

A graduate of Pennsylvania State College in the Class of 1900, he went to Iowa State College, where he was an instructor in mining and a graduate student, leading to the degree of Engineer of Mines. Becoming professor of mining engineering at Colorado School of Mines, he remained at Golden from 1904 until 1907 when he was appointed director of the Missouri School of Mines. He served there for six years, until he joined the Illinois Geological Survey with which he was associated until 1917. While with the Survey, he also became assistant professor of business administration at the University of Illinois and did graduate work, earning the degree of Doctor of Philosophy. An honorary Doctor of Engineering was conferred upon him by Missouri School of Mines and by Colorado School of Mines.

In 1918, Lewis Young began his

association with Union Collieries Co. of St. Louis, first as a mining engineer and later as general manager. In 1947, he became production vice-president of the Pittsburgh Coal Co.

From 1939 until his death, Dr. Young was engaged as a consulting engineer. He was especially interested in development, operation, and management of mines in coal, limestone, potash, and copper in the United States and Canada. He inspected mines in South America, Turkey, England, Scotland, and Germany.

Lewis E. Young joined the American Institute of Mining and Metallurgical Engineers in 1901 and became a Member of the Legion of

L. E. YOUNG

Honor in 1951. He served as Director from 1937 to 1941, Vice-President from 1941 to 1945, and President in 1949. Greatly devoted to the Institute, he was active in its meetings and contributed frequently to its publications. He was an Honorary Member of the Institute of Mining Engineers of England, and a member of state mining organizations and professional societies in the United States.

RESOLUTION

WHEREAS, LEWIS E. YOUNG achieved eminent success in three principal fields of activity in mining as teacher, mine official, and consulting engineer, and rendered distinguished service to the American Institute of Mining and Metallurgical Engineers as Member, Director, Vice-President, and President, therefore be it

RESOLVED, that the Directors of the Institute, convened at the meeting in January 1954, express their high regard for Lewis E. Young; their great sense of loss in his death; and enter this resolution in the minutes of the meeting, and send a copy to Mrs. Lewis E. Young.

The year 1949, when Lewis E. Young was President of the Institute, coincided with my first year as Secretary. It was a year of major reorganization, of four-hour Board meetings, of establishment of three new journals. Dr. Young's contribution of time, talent, interest, effort, and money in this emergency was priceless. To me, especially in that year, but in earlier and later years as well, his wise counsel and friendly cooperation will never be forgotten. He was a man of great professional ability, keen and earnest interest in everything he set out to do, unsparing of himself in the things that he undertook. He was a favorite of the Institute staff, of whom he knew a large number. One of the most distinguished characteristics of a gentleman is that he does not discriminate in his interest or courtesy, and on this score Dr. Young ranked at the top.

A multitude of Institute members will sincerely and personally mourn his sudden death.—Edward H. Robie.

Necrology

Date Elected	Name	Date of Death
1919	George S. Baton	Dec. 28, 1953
1928	Frank M. Brewster	May 1953
1915	John L. Dynan	Nov. 24, 1953
1921	Ellis A. Hall	Unknown
1930	P. E. Henry	Unknown
1949	Geoffrey Jeffreys	Oct. 28, 1953
1937	R. W. Michael	Dec. 22, 1953
1949	Ralph G. Mickle, Jr.	Nov. 24, 1953
1940	William H. Nikola	Dec. 17, 1953
1952	Richard Schoof, Jr.	Dec. 4, 1953
1916	A. T. Ward	Dec. 15, 1953
1883	Pope Yeatman	Dec. 5, 1953
1901	Lewis E. Young	Dec. 27, 1953

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on December 31, 1953 was 19,718; in addition 2195 Student Associates were enrolled.

ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; Philip D. Wilson, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Gensamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, George N. Lutjen, E. A. Prentis, Sidney Rolle, John T. Sherman, Frank T. Sisco, R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Alabama

Bessemer—Davis, John L. (M)
Birmingham—Hillhouse, Harry P., Jr. (A)
Birmingham—Marshall, Clarence G. (M)
Fairfield—Marshall, Robert T. (M)
Gorgas—Cox, Ralph H. (J)
Gorgas—Stull, Chester J., Jr. (J)
Tuscaloosa—Perry, Richmond E. (M)
University—Lamont, William E. (J)

Arizona

Mammoth—Hallett, Alfred F., Jr. (J)
Patagonia—Jameson, Donald R. (R. C/S—S-M)
Tucson—Congdon, Stephen H. (R. C/S—S-J)
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FEATURES: Sensitivity control may be adjusted so that instrument reacts to or ignores foam.

DESCRIPTION: Liquid level controller reacts to a change in capacity when probe is covered by a liquid or other flowable material. Capacitance change causes a radio-frequency oscillator to reduce or completely stop oscillation when level rises above the probe. Oscillation starts again when level falls below the probe. This change in operation is used to generate a DC voltage signal, which through an amplifier, operates the relay. A plug-in type relay is normally furnished with a DPDT set of contacts—other arrangements may be obtained for special applications.

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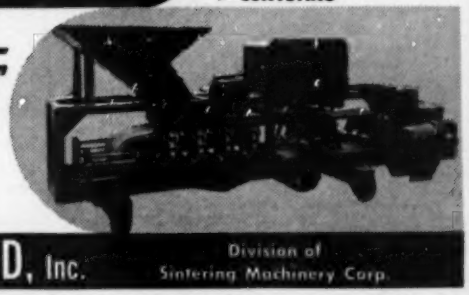

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— Coming Events —

Feb. 15-18, AIME, Annual Meeting, Mining and Petroleum Branches, Hotel Statler; Metals Branch, Hotel McAlpin, New York.

Feb. 16, Michigan School of Mines, cocktail party and dinner 6:00 pm, Penn Top North, Statler Hotel, New York.

Feb. 16, Montana School of Mines Alumni Group, cocktails at 6:30 pm, dinner 7:30 pm, Parlor A, Statler Hotel, New York. Ladies invited.

Feb. 25-27, Coal Trade Assn. of Indiana, Annual Meeting, Terre Haute, Ind.

Mar. 3, AIME, Chicago Local Section, Chicago Bar Assn., Chicago.

Mar. 8-10, American Institute of Chemical Engineers, Statler Hotel, Washington, D. C.

Mar. 10, AIME, Connecticut Local Section, American Brass Co., Torrington, Conn.

Mar. 11, AIME, Utah Section, dinner with Woman's Auxiliary, Salt Lake City.

Mar. 15-19, National Assn. of Corrosion Engineers, Municipal Auditorium, Kansas City.

Mar. 17, AIME, National Open Hearth Steel Committee, Western Section, Rodger Young Auditorium, Los Angeles.

Mar. 18, Central Pennsylvania Coal Producers Assn., Penn-Alto Hotel, Altoona, Pa.

Mar. 23, Techno-Sales Conference, for members, Bituminous Coal Research, Neill House, Columbus, Ohio.

Apr. 5-7, AIME, Blast Furnace, Coke Oven, Raw Materials, and National Open Hearth Conference, Palmer House, Chicago.

Apr. 7, AIME, Chicago Local Section, Chicago Bar Assn., Chicago.

Apr. 21-23, Southern Industrial Wastes Conference, Hotel Shamrock, Houston.

Apr. 26-28, Canadian Institute of Mining and Metallurgy, Annual Meeting, Mount Royal Hotel, Montreal.

Apr. 26-30, American Society of Tool Engineers' Industrial Exposition, Convention Center, Philadelphia.

Apr. 27, Open Meeting of the Assn. of Consulting Chemists and Chemical Engineers Inc., Hotel Belmont Plaza, New York.

Apr. 30-May 1, Pacific Northwest Metals and Minerals Conference of 1954, joint meeting of Metals Branch and Industrial Minerals Div., Portland, Ore.

May 2-6, Electrochemical Society, La Salle Hotel, Chicago.

May 3-5, Coal Convention of the American Mining Congress, Cincinnati.

May 3-8, International Conference on Complete Gasification of Coal, Inichar, Liége, Belgium.

May 8-14, American Foundrymen's Society, Cleveland Auditorium, Cleveland.

May 9-11, Southeastern Retail Coal Assn., Annual Convention, Atlanta-Biltmore Hotel, Atlanta, Ga.

May 17-19, Indiana Coal Merchants Assn., Annual Meeting, French Lick, Ind.

May 24-25, Ohio Coal Conference, Annual Convention, Neill House, Columbus, Ohio.

May 24-27, Symposium on Instrumentation Industrial Hygiene, University of Michigan, Ann Arbor.

May 26-28, Southern Appalachian Industrial Exhibit, Bluefield, W. Va.

May 27, Central Pennsylvania Coal Producers Assn., Penn-Alto Hotel, Altoona, Pa.

June 4, Big Sandy-Elkhorn Coal Operators Assn., Annual Meeting, Lexington, Ky.

June 14-18, Second U. S. Congress of Theo. & Appld. Mech. Meeting, University of Michigan, Ann Arbor.

June 20-24, American Society of Mechanical Engineers, Wm. Penn Hotel, Pittsburgh.

June 23-26, American Coal Sales Assn., Annual Convention, Colorado Springs, Colo.

Sept. 24, AIME, Minerals Beneficiation Div., Fall Meeting, San Francisco.

Oct. 5-9, AIME Industrial Minerals Div., Fall Meeting, Whiteface Inn, Lake Placid, N. Y.

Oct. 28-29, AIME, ASME Fuels Conference, William Penn Hotel, Pittsburgh.

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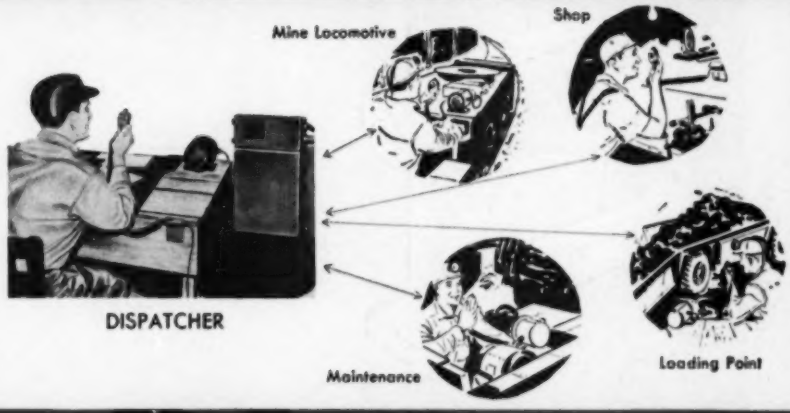

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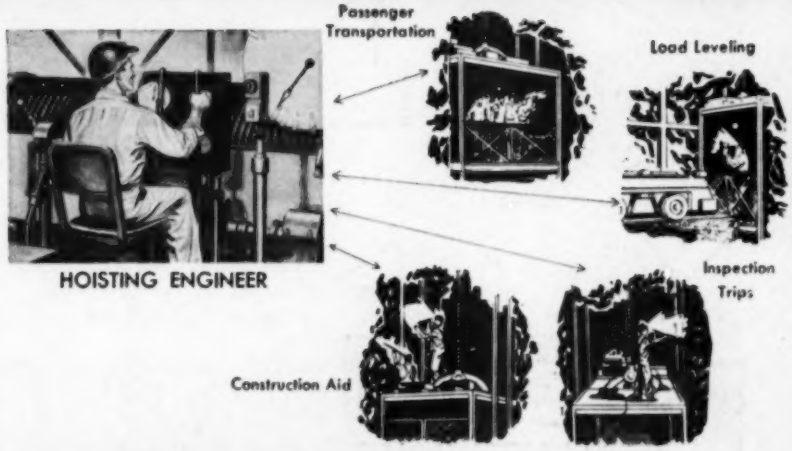

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